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METHOD FOR PRODUCING A PART FROM STEEL SHEET

Bernard S. Levy, Chicago, Ill., assignor to Inland Steel Company, Chicago, Ill.

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11 Claims

ABSTRACT OF THE DISCLOSURE

Steel having 0.04 wt. percent carbon and 0.25–1.00 wt. percent manganese is provided with a strengthening addition of either (1) 0.008 wt. percent nitrogen or (2) said nitrogen content plus 0.05–0.25 wt. percent silicon. The steel is rolled into a coil of rolled steel sheet having a yield strength of about 40,000–50,000 p.s.i. A steel part is formed from the sheet in a forming operation which increases the yield strength to about 60,000–65,000 p.s.i.; and the steel part is then age hardened at an elevated temperature to increase the yield strength to about 65,000–75,000 p.s.i. An optional heavy temper roll is performed when the forming operation is relatively mild.

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation in part of application Ser. No. 743,295 filed July 9, 1968, and now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to a method for forming, from steel sheet, either hot rolled or cold rolled, galvanized or uncoated, a part which, after forming and ageing, has a relatively high yield strength between about 65,000 and 75,000 p.s.i.

As used herein, the term *sheet* includes strip. Steel sheet is made by a rolling operation performed at a rolling mill which ships the sheet to a fabricator customer forming into a part. During forming, the yield strength of the steel is increased.

A conventional way of assuring that a formed steel part has a desired yield strength of about 65,000–75,000 p.s.i. is to form the part from steel sheet having this desired yield strength. However, forming parts from steel sheet of this yield strength is difficult because the relatively high yield strength is accompanied by a relatively low ductility.

Steels of relatively high ductility, such as A.I.S.I. 1008 steel conventionally used for steel sheets subjected to forming operations, have a relatively low yield strength. As rolled, A.I.S.I. 1008 steel sheet has a yield strength of 25,000–40,000 p.s.i. depending upon whether it is cold rolled and annealed (25,000–30,000 p.s.i.) or hot rolled, the hot rolled giving the higher yield strength; and even should the yield strength of A.I.S.I. 1008 steel sheet be increased by the forming operation, and by age hardening, the resulting yield strength of the part is still too low.

Steel sheet which has been strained (as by forming) age hardens, and this increases its yield strength. The full effect of age hardening at ambient temperatures would accrue in 80 to 90 days. Products formed from steel sheets are conventionally subjected to a painting operation followed by a curing operation at elevated temperatures, e.g., 350° F., for about thirty minutes and this accelerates the age hardening of the steel, which in turn accelerates the accompanying increase in yield strength.

After forming and accelerated ageing due to the curing operation, a product formed from conventional A.I.S.I. 1008 steel sheet, cold rolled and annealed or hot rolled, has a yield strength of about 50,000–60,000 p.s.i., the hot rolled being higher. This yield strength is 10,000–20,000 p.s.i. lower than that desired.

Because age hardening decreases ductility and makes forming more difficult, it has been conventional practice to minimize age hardening characteristics in steel sheet intended for forming.

SUMMARY OF THE INVENTION

A method in accordance with the present invention purposely relies on the increase in yield strength resulting from forming and from age hardening at an elevated temperature to achieve the desired yield strength in a part formed from the steel sheet. However, at the time the steel sheet undergoes forming, the yield strength is sufficiently low and the ductility is sufficiently high, to permit forming without difficulty.

A steel part formed in accordance with the present invention will have a yield strength, at the conclusion of forming (10% deformation) and age hardening operations, of between about 65,000 and 75,000 p.s.i. The increase in potential yield strength over that of a part made from A.I.S.I. 1008 steel (50,000–60,000 p.s.i.) accrues from both the rolling operation conducted at the mill and from the forming operation conducted by the customer. In addition, the incremental potential increase in yield strength, resulting from age hardening during a curing operation, remains the same as with the conventional A.I.S.I. 1008 steel; so that no part of the net increase in potential yield strength over the 1008 steel, accruing from the rolling and forming operations, is lost during the age hardening operation.

These improvements in yield strength are obtained by adding to a base steel, corresponding essentially to an A.I.S.I. 1008 steel, a strengthening addition consisting essentially of (1) 0.008–0.015 wt. percent nitrogen or (2) said nitrogen content plus 0.05–0.25 wt. percent. The silicon and the nitrogen each impart additional yield strength to the base steel during both the rolling operation and the forming operation. In addition, the silicon minimizes the tendency of a product formed from the steel to undergo a gradual decrease in tensile properties over a period of years.

The composition described in the preceding paragraph provides a rolled sheet having higher than usual initial yield strength together with sufficient ductility for forming, maximum work-hardening properties and desired age hardening characteristics.

Finishing procedures, during the hot rolling operation, and heat treating procedures, following the cold rolling operation, must also be controlled to impart the desired properties to the steel sheet.

Other features and advantages are inherent in the composition and method claimed and disclosed or will become apparent to those skilled in the art from the following detailed description.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A steel sheet in accordance with the present invention has a composition essentially within the following ranges:

Element	Weight percent	
	Permissible	Preferable
Carbon	0.04–0.18	0.7–0.10
Manganese	0.25–1.00	0.45–0.65
Nitrogen	0.008–0.115	0.009–0.11
Silicon (optional)	0.05–0.25	0.08–0.12
Iron	Essentially the balance	

Other elements normally present in steel in residual amounts, e.g. sulphur and phosphorus, may also be present in residual amounts.

When the steel is teemed into ingots, rimming is avoided but without adding aluminum or titanium.

A steel having a composition in the range outlined above may be rolled into sheets by a hot rolling or cold rolling operation. If the sheet is hot rolled, it may, optionally, also be pickled and/or temper rolled.

The hot rolling operation is essentially conventional up to the finishing step which is conducted at a finishing temperature in the range 1450°–1600° F. (1520° F. preferable). The finished hot rolled strip is then coiled at a coiling temperature in the range 950°–1150° F. (1050° F. preferable). Hot rolled steel sheet finished and coiled as described above has an average ferrite grain size in the range 7–11 and a yield strength of about 45,000–50,000 p.s.i.; and this hot rolled steel sheet, after cooling to room temperautre and pickling, is used as the starting material for producing a cold rolled steel sheet in accordance with the present invention.

The cold rolling operation is essentially conventional, but, in order to obtain the above described properties, in accordance with the present invention the cold rolling operation may be followed by a heat treating operation of the continuous normalizing type rather than batch annealing as on 1008 steel. The continuous normalizing operation comprises heating the cold rolled steel sheet at a sheet temperature in the range 1550°—2000° F. for a time in the range of five seconds to five minutes followed by a cooling step in which the sheet undergoes cooling down to a temperature of 200° F. at an average cooling rate in the range 200° F. per minute to 2000° F. per minute. In a preferable embodiment, the cold rolled steel sheet is heated at a sheet temperature in the range 1750°–1850° F. for ten to fifteen seconds and cooled at an average cooling rate of 800° F. per minute.

Following the continuous normalizing operation, the cold rolled sheet is subjected to a relatively mild temper rolling step. A cold rolled sheet, prepared as described above, has a ferrite grain size in the range 6–11 and a yield strength of 40,000–45,000 p.s.i.

Optionally, the cold rolled steel sheet may be box annealed at a temperature in the range of about 1035°–1085° F. for 6–12 hours and then furnace cooled, for example.

Unless specified to the contrary, as used subsequently herein, the term *cold rolled* refers to a steel sheet which has been not only deformed by cold rolling but also subjected to the above described continuous normalizing step or a batch annealing step and to a temper rolling step. As used herein, the term *annealing,* when used in connection with cold rolled steel sheet, includes both batch annealing and continuous normalizing.

Either the hot rolled or cold rolled steel sheet may be galvanized. When producing galvanized cold rolled sheet, the continuous normalizing operation described above should be incorporated into the galvanizing line, upstream of the conventional hot dip bath; and the step of dipping the sheet into a bath of molten zinc should be performed during the time the sheet is undergoing said cooling at a cooling rate in the range 200° F. per minute to 2000° F. per minute. This heat treating step is also recommended when galvanizing the hot rolled sheet.

The yield strength of the steel sheet is slightly lower when cold rolled (40,000–45,000 p.s.i.) than when hot rolled (45,000–50,000 p.s.i.). In either condition, the yield strength is somewhat higher than that of a conventional A.I.S.I. 1008 steel after rolling (25,000–30,000 p.s.i. cold rolled and annealed, and up to 40,000 p.s.i. hot rolled).

As hot or cold rolled, the steel sheet of the present invention has a uniform elongation of about 16%. These and other moderate tensile properties render the steel formable without difficulty.

The rolled steel sheet is shipped to the customer who performs a pressing, drawing or other conventional forming operation on the steel sheet. At the conclusion of a typical forming operation, e.g. 10% strain, a product made from steel sheet in accordance with the present invention has a yield strength of about 60,000 to 65,000 p.s.i. This is about 10,000–20,000 p.s.i. greater than the yield strength of the rolled sheet before forming. A yield strength, after forming, in the range 60,000 to 65,000 p.s.i. is at least 10,000 p.s.i. greater than the yield strength after the same forming operation of a product made from A.I.S.I. 1008 steel sheet, either cold rolled and annealed or hot rolled. Part of this 10,000 p.s.i. difference is due to a net increase accuring from the rolling operation and part of this difference is due to a net increase accruing from the forming operation.

Conventionally, formed steel parts are painted in a conventional manner ad then subjected to a curing operation typically conducted at about 350° F. The curing operation may be performed at a temperature in the range of 200–500° F. for a time of about 7½ minutes to about 120 minutes, any curing operation performed in this range producing essentially no difference in the final properties of the steel.

In accordance with the present invention, forming and curing are performed before the steel fully age hardens; and the increase in yield strength resulting from age hardening occurring during the curing operation is about another 8,000 p.s.i., for example, giving a final yield strength for a product made from steel sheet in accordance with the present invention of about 70,000 p.s.i. The 8,000 p.s.i. increase in yield strength due to age hardening is about the same as the increase resulting from the age hardening of conventional A.I.S.I. 1008 steel sheet.

Thus, a product made from steel sheet in accordance with the present invention has a net increase in yield strength accuring from both the rolling and the forming operations, while maintaining the same increase in yield strength during the age hardening operation, as compared to a product made from conventional A.I.S.I. 1008 steel sheet.

Contributing to this net increase in yield strength are the silicon and nitrogen in the amounts indicated above.

The silicon also serves another function. There is a likelihood of the steel undergoing a gradual decrease in tensile properties over a period of years. The presence of the silicon minimizes this decrease.

A specific example of a preferred embodiment has the following composition, in wt. percent, in addition to iron:

Carbon	0.09
Managanese	0.65
Phosphorus	0.009
Sulfur	0.017
Aluminum	0.006
Silicon	0.11
Nitrogen	0.011

In a hot rolled, pickled and oiled condition, a steel sheet rolled from the above composition had the following typical tensile properties:

Yield strength, p.s.i.	50,500
Tensile strength, p.s.i.	63,500
n factor	.18
Uniform elongation, percent	16.4
Total elongation (in 2 in.), percent	28.4

In a cold rolled condition, the steel sheet had the following typical tensile properties:

Yield strength, p.s.i.	45,600
Tensile strength, p.s.i.	64,000
n factor	.20
Uniform elongation, percent	16.4
Total elongation (in 2 in.), percent	26.1

When samples of the steel sheet described above were formed (10% strain) and then age hardened at a series of temperatures running from 200° F. to 500° F. and at a series of times at each temperature, running from 7½ minutes to 120 minutes, the resulting yield strength was always in the range of 71,000–74,000 p.s.i., and the product always remained relatively ductile having a total elongation (in 2 in.) in the range of 11–14%.

The cold rolled embodiment of the steel has slightly lower strengths, as rolled, than does the hot rolled embodiment; but, after forming and age hardening, the properties of both embodiments are substantially the same.

Similar results are obtainable using the same composition without silicon.

The foregoing description assume that the forming operation performed outside the rolling mill by the fabricator is sufficiently severe to impart an increase in yield strength to the steel of up to about 20,000 p.s.i. and at least about 10,000–15,000 p.s.i. If this forming operation is relatively mild or is severe only at one part of the steel while mild in other parts, the increase in yield strength at the mildly deformed parts of the steel will be substantially less than 10,000–15,000 p.s.i. Accordingly, the final yield strength after age hardening for these parts would be somewhat less than the yield strength aim of 70,000 p.s.i.

In accordance with an embodiment of the present invention, this drawback is overcome by subjecting the steel at the mill to a relatively heavy temper roll, e.g. 2% to 10% deformation, to make up the difference between the increase in yield strength obtainable with a relatively severe forming operation (up to about 20,000 p.s.i. and at least about 10,000–15,000 p.s.i.) and the increase in yield strength actually obtained by the relatively mild forming operation. For example, if the yield strength, as rolled, is in the range 45,000–50,000 p.s.i. and the increase in yield strength of most of the steel product, due to forming, is only about 5,000 p.s.i. rather than 15,000 p.s.i., the difference between the two (10,000 p.s.i.) is made up by subjecting the steel to a relatively heavy temper roll at the mill sufficient to impart an additional 10,000 p.s.i. increase in yield strength to the steel to bring the yield strength up to about 70,000 p.s.i.

Generally, for hot rolled sheet, the temper rolling operation is for increasing the yield strength before forming by about 10,000–15,000 p.s.i. minus the increase in yield strength resulting solely from the forming operation, while, for cold rolled sheet, the temper rolling operation is for increasing the yield strength before forming by about 15.000–20,000 p.s.i. minus the increase in yield strength resulting solely from the forming operation. Rolled steel sheet having the composition and yield strength described above and subjected to relatively heavy tempering (e.g., 4–8% deformations), in accordance with the present invention, does not undergo substantial age hardening at ambient temperatures.

What is claimed is:

1. A method for forming, from steel sheet, a part having a yield strength in the range of about 65,000–75,000 p.s.i., said method comprising the steps of:

providing a steel consisting essentially of, in wt. percent:

0.04–0.18 carbon,

0.25–1.00 manganese,

a strengthening addition selected from the group consisting of (1) 0.008–0.015 nitrogen and (2) said nitrogen content plus 0.05–0.25 silicon,

and a balance consisting essentially or iron;

rolling said steel to produce a coil of rolled steel sheet having a yield strength in the range of about 40,000–50,000 p.s.i. and having age hardening characteristics at an elevated temperature;

forming said steel part from said rolled steel sheet in a forming operation which increases the yield strength of the steel to within the range of about 60,000–65,000 p.s.i.;

and then age hardening said steel part at an elevated temperature to increase the yield strength of said steel to within the range of about 65,000–75,000 p.s.i.

2. A method as recited in claim 1 and comprising the further steps of:

temper rolling said steel sheet before said forming step to increase the yield strength of the steel by about 10,000–20,000 p.s.i. minus the increase in yield strength resulting solely from said forming step.

3. A method as recited in claim 2 wherein said temper rolling step comprises deforming said steel sheet about 4–8% without imparting thereto substantial ambient temperature age hardening characteristics.

4. A method as recited in claim 1 wherein said steel is painted between said forming step and said age hardening step.

5. A method as recited in claim 1 wherein said age hardening step is performed at a temperature in the range 200°–500° F. for a time in the range 7½–120 minutes.

6. A method as recited in claim 1 wherein:

said rolling step comprises hot rolling said steel to provide a coil of hot rolled steel sheet having a yield strength in the range of about 45,000–50,000 p.s.i.;

and said steel part is formed from said steel sheet with the sheet in a hot rolled condition.

7. A method as recited in claim 6 and further comprising:

temper rolling said hot rolled steel sheet before said forming step to increase the yield strength of the steel by about 10,000–15,000 p.s.i. minus the increase in yield strength resulting solely from said forming step.

8. A method as recited in claim 7 and comprising:

temper rolling said sheet to impart thereto a deformation in the range 4–8% without imparting thereto substantial ambient temperature age hardening characteristics.

9. A method as recited in claim 1 wherein:

said rolling step comprises cold rolling and annealing said steel to provide a coil of cold rolled steel sheet having a yield strength in the range of about 40,000–45,000 p.s.i.;

and said steel part is formed from said cold rolled steel sheet.

10. A method as recited in claim 9 and further comprising:

temper rolling said cold rolled steel sheet before said forming step to increase the yield strength of the steel by about 15,000–20,000 p.s.i. minus the increase in yield strength resulting solely from said forming step.

11. A method as recited in claim 10 and comprising:

temper rolling said sheet to impart thereto a deformation in the range 4–8% without imparting thereto substantial ambient temperature age hardening characteristics.

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L. DEWAYNE RUTLEDGE, Primary Examiner

W. W. STALLARD, Assistant Examiner

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,673,009 **Dated** June 27, 1972

Inventor(s) Bernard S. Levy

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

Column 2, line 38, after "wt. percent" insert --silicon--.

Column 2, line 70, the permissible wt. % for nitrogen should read "0.008-0.015".

Signed and sealed this 2nd day of January 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents