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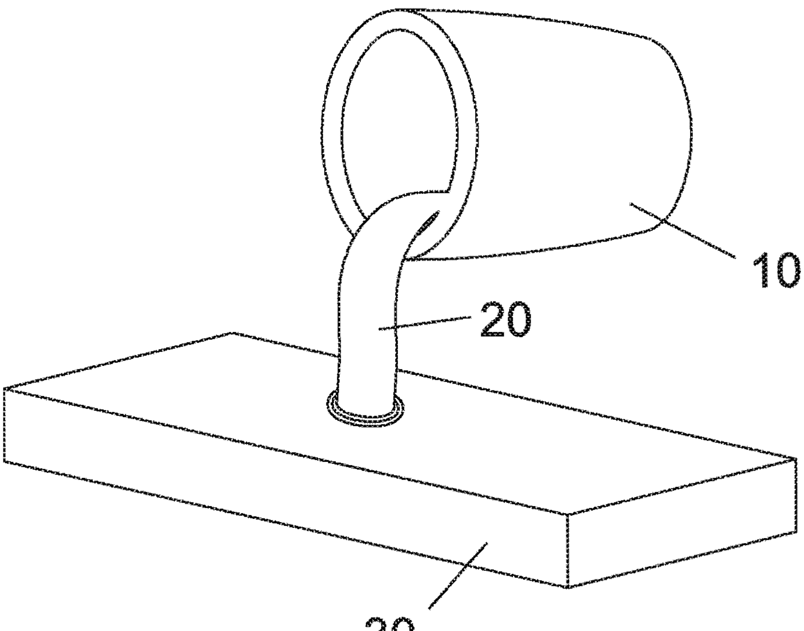

Figure 1A

(57) Abrégé/Abstract:
The present invention describes a novel steel sheet or plate formed of a martensitic steel alloy having iron, at least some of the iron having dislocations; less than 5% of any combination of nickel, manganese, and copper; from about 0.0001% to about 0.01% boron; from about 0.075% to about 6.5% titanium; more than 0.003% and less than 0.1% carbon; and less than 7% of all other elements. The steel has substantially no cementite, the titanium has clustered at the dislocations, and the steel sheet or plate has been formed by quenching off of a hot sheet or plate mill.

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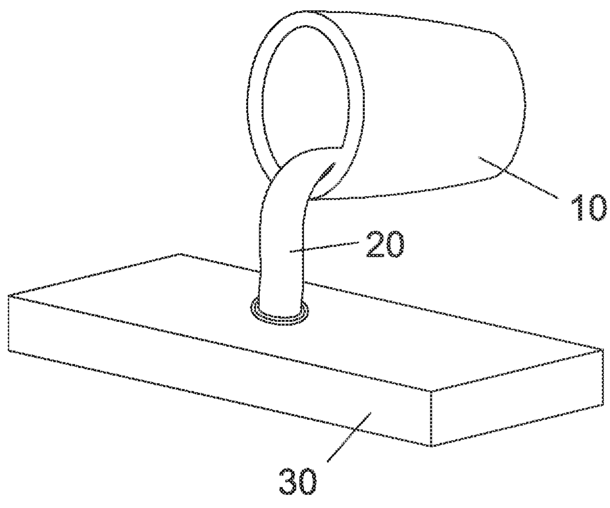

Figure 1A

(57) Abstract: The present invention describes a novel steel sheet or plate formed of a martensitic steel alloy having iron, at least some of the iron having dislocations; less than 5% of any combination of nickel, manganese, and copper; from about 0.0001% to about 0.01% boron; from about 0.075% to about 6.5% titanium; more than 0.003% and less than 0.1% carbon; and less than 7% of all other elements. The steel has substantially no cementite, the titanium has clustered at the dislocations, and the steel sheet or plate has been formed by quenching off of a hot sheet or plate mill.

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[Continued on next page]

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IMPACT RESISTANT HIGH STRENGTH STEEL

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] In those jurisdictions where a priority claim is proper, this application claims the benefit of U.S. Patent Application Serial No. 15/989,705 entitled "IMPACT RESISTANT HIGH STRENGTH STEEL," filed on May 25, 2018, and claims the benefit of PCT Application Serial No. PCT/US2018/036332 entitled "IMPACT RESISTANT HIGH STRENGTH STEEL," filed on June 6, 2018, the contents of all of which are incorporated in this disclosure by reference in their entirety.

BACKGROUND

[0002] In order to decrease fuel consumption, increase safety and accelerate commercialization of aircraft, automobiles and other motor driven platforms, high strength materials have been developed with advantageous properties such as reduced weight and increased strength. However, many of these new materials have the disadvantage of high cost, making widespread usage unaffordable, thus restricting these materials to niche applications.

[0003] The steel industry has met this need with a general family of steels collectively known as Advanced High Strength Steels. These steels, including interstitial free steels, Dual/Complex Phase, Transformation Induced Plasticity and martensite have been used in the automotive industry; however, they are reaching limits on specific mechanical properties and affordability. Therefore, there is a need for a new type of steel that has advantageous properties and reduced cost, thereby reducing weight, increasing safety, and maintaining or increasing affordability.

SUMMARY

[0004] The present invention provides a steel sheet or plate formed of a martensitic steel alloy comprising: a) iron, at least some of the iron having dislocations; b) less than 5% of any combination of nickel, manganese, and copper; c) from about 0.0001 to about 0.01% boron; d) from about 0.05% to about 6.5 % titanium; e) more than 0.003% and less than 0.1% carbon; and f) less than 7% of all other elements. The alloy has substantially no copper and substantially no cementite. In one aspect, the alloy is substantially a martensitic structure with minor ferrite zones and the titanium has clustered at the dislocations.

[0005] In one aspect, the alloy comprises more than 0.1% titanium. In another aspect, the alloy comprises more than 0.12% titanium. In another aspect, the alloy comprises more than 0.14% titanium. In another aspect, the alloy comprises more than 0.2% titanium.

[0006] In one aspect, the alloy comprises less than 0.5% of any combination of nickel, manganese, and copper. In another aspect, the alloy comprises less than 1% of any combination of nickel, manganese, and copper. In another aspect, the alloy comprises less than 1.5% of any combination of nickel, manganese, and copper. In another aspect, the alloy comprises less than 2% of any combination of nickel, manganese, and copper. In another aspect, the alloy comprises less than 2.5% of any combination of nickel, manganese, and copper. In another aspect, the alloy comprises less than 3% of any combination of nickel, manganese and copper.

[0007] In one aspect, the alloy comprises less than 0.05% carbon. In another aspect, the alloy comprises less than 0.04% carbon. In another aspect, the alloy comprises less than 0.03% carbon. In another aspect, the alloy comprises less than 0.02% carbon. In another aspect, the alloy comprises less than 0.01% carbon.

[0008] In one aspect, the alloy comprises at least 0.025% aluminum.

[0009] In one aspect, the steel sheet or plate can be cold rolled. Optionally, the steel sheet or plate has been hot dip coated in zinc or an alloy containing zinc without substantially crystallizing the martensitic steel structure. Optionally, the steel sheet or plate can be formed by quenching off of a hot sheet or plate mill.

[0010] After quenching, or after cold roll, the sheet can be reheated to a temperature of between 200 C and 750 C and maintained at that temperature for more than one minute.

[0011] In another aspect, the present invention is a method of making a steel sheet or plate formed of a martensitic steel alloy. The method comprises the steps of: a) heating the alloy steel to a sufficiently high temperature that the steel transitions to an austenitic, face centered cubic lattice phase and the titanium removes substantially all of the carbon from the crystal lattice by forming a metal carbide other than iron carbide; b) hot rolling the heated alloy steel of step (a); and c) quenching the hot rolled steel of step (b) a quench temperature with a quench faster than still air such that a body centered cubic lattice is formed by displacement.

[0012] In one aspect, the method comprises cold rolling the alloy steel to form the sheet or plate before the step of quenching.

[0013] In one aspect, the quench temperature is from about 200 to about 750 degrees C.

[0014] In one aspect, the step of heating comprises heating to a temperature greater than 1000 degree C.

[0015] In one aspect, after quenching, the hot rolled steel is maintained at a temperature of greater than 200 degree C for a sufficient time to form order intermetallics.

[0016] In one aspect, after quenching, the rolled steel is heated to a reheat temperature of between 200 C and 750 C and maintaining it at the reheat temperature for more than one minute.

[0017] In one aspect, the method comprises the additional step of hot dip coating the rolled steel in zinc or an alloy containing zinc without substantially crystallizing the martensitic steel structure.

[0018] This invention has applications outside the automotive industry, and is useful wherever high strength, low cost steel is desirable.

DRAWINGS

[0019] The detailed description of some embodiments of the invention is made below with reference to the accompanying Figures 1A-1B.

[0020] Figure 1A is a schematic of steps involved in a method of making steel according to the present invention; and

[0021] Figure 1B is a schematic of steps involved in the method of making steel according to the present invention.

DESCRIPTION

[0022] As used herein, the following terms and variations thereof have the meanings given below, unless a different meaning is clearly intended by the context in which such term is used.

[0023] The terms "a," "an," and "the" and similar referents used herein are to be construed to cover both the singular and the plural unless their usage in context indicates otherwise.

[0024] Definitions of chemical terms and general terms used throughout the specification are described in more detail herein, but unless otherwise indicated the chemical elements are identified in accordance with the Periodic Table of the Elements, CAS version, Handbook of Chemistry and Physics, 75th Ed., inside cover, or are terms that are well known to one of skill in the art.

[0025] Percentages referred to herein are percentages by weight.

[0026] As used in this disclosure, the term "comprises" and variations of the term, such as "comprising" and "comprises," are not intended to exclude other additives, components, ingredients or steps.

[0027] As used herein, "dislocation" refers to a crystallographic defect or irregularity within a crystal structure of a material on an atomic scale. The presence of dislocations influences many of the properties of materials. Transmission electron microscopy (TEM) can be used to observe dislocations within the crystal structure of the material.

[0028] Interstitial free steel is well known in the steel industry where the higher cost of these types of steels are acceptable due to the excellent forming properties and a lack of yield point elongation. These steels typically have low yield strength, high plastic strain ratio, high strain rate sensitivity and good formability. Interstitial free steels have interstitial free body centered cubic ferrite matrix. Carbon is kept very low and is stabilized, or removed, from the crystal lattice structure of the steel, normally with titanium, niobium or both. The disadvantage of these steels is the relatively low strength of the ferrite.

[0029] Austenite steel has a face-centered cubic crystal structure. The carbon atoms lie in the interstices (holes) between the larger iron atoms. At slow cooling rates, the carbon moves ahead of the interface into the austenite iron by diffusion. Austenite steel may be strengthened by rapid cooling (quenching) by, for example, immersing the hot metal into liquid coolants such as water, oil, or liquid salts. Steels can also be quenched by air.

[0030] The term “martensitic steel alloy”” is defined herein to be any steel or alloy steel that transitions from a face centered cubic lattice phase to a body centered cubic lattice phase predominantly by displacement and/or shear and not by substitution. When austenite is rapidly cooled, a martensite phase is formed. Martensite, tempered martensite and bainite are high strength steels that are well known in the steel industry where very high strength is required. Bainite steel is within the definition of martensitic steel alloy.

[0031] In tempered martensite and bainite, the carbon migrates out of the lattice structure and forms a metal carbide. The disadvantage of these steels is the high carbon content required to form martensite. This causes a reduction in elongation and toughness with an inverse relationship to the increase in strength.

[0032] Additionally, Maraging and PH stainless steels are well known in the aerospace industry, where the higher cost of these types of steels are acceptable due to the excellent properties inherent in precipitating a nickel intermetallic. All current generation advanced high strength steels rely on carbon to some extent to add strength and/or facilitate other reactions. Maraging and PH stainless steels rely on formation of a martensitic steel matrix and, with aging, precipitation of a nickel intermetallic with aluminum, molybdenum, titanium, niobium, tantalum or other metals known to those skilled in the art. A typical Maraging steel may be composed of 18% - 19% nickel, 8% - 10% cobalt, 3% - 5.5% molybdenum, 0.15% - 1.6% titanium and 0.5% niobium, and after aging exceed 2,400 MPa yield and tensile strength. A typical PH stainless steel may be composed of 15% chrome, 4% nickel, 3% copper, and 0.15% - 0.45% of tantalum and niobium. Carbon is kept low. This family of alloys will form martensite upon slow heat of the metal to a solution treatment temperature, and then let the metal air cool to room temperature, which forms intermetallics. The disadvantage of these steels is the high alloy content required to form a martensite steel matrix with slow cooling rates. The high alloy content also increases cost beyond what a high-volume application can justify.

[0033] Thus, there is a need for high strength interstitial free or predominantly interstitial free steel that is capable of forming shear martensite without high alloy additions and without carbon in the crystal lattice structure.

[0034] This invention provides a material that contains low alloy additions that remove carbon from the high temperature face centered crystal lattice and enable an industry standard quench to transform the steel to an interstitial free martensite without a temper treatment. When higher strength is required, the material of the invention may be heated to a precipitation hardening temperature to form an additional ordered intermetallic. The martensitic steel of the invention has substantially all of the carbon removed from the crystal lattice of the austenite prior to forming martensite, forming an interstitial free martensite that is strengthened not with carbon/carbon iron but by pinning the dislocations with an intermetallic.

[0035] In particular, the present invention provides a new type of a steel sheet or plate formed of a martensitic steel alloy comprising: a) iron, at least some of the iron having dislocations; b) less than about 5% of any combination of nickel, manganese, and copper; c) from about 0.0001% to about 0.01% boron; d) from about 0.05% to about 6.5% titanium; e) more than about 0.003% and less than about 0.1% carbon; and f) less than about 7% of all other elements. “All other elements” means elements other than iron, nickel, manganese, copper, boron, titanium, and carbon.

[0036] The steel preferably has substantially no cementite, substantially no interstitial carbon, substantially no interstitial nitrogen, and substantially no copper. The steel has titanium dispersed in the iron with the titanium clustered at the dislocations. Optionally, the steel is substantially a martensitic structure with minor ferrite zones. The sheet or plate is typically formed by quenching off of a hot sheet or plate mill. The method of making the steel is discussed in more detail below.

[0037] Titanium and boron are very strong hardenability agents that are believed to work synergistically together to form martensite without the normal carbon additions that are used in plain carbon and alloy steel or the high alloy concentrations used in Maraging and PH stainless steels. Boron may also increase elongation and blunt crack propagation at grain boundaries and at the nickel intermetallic.

[0038] The titanium serves as a carbide former. Other carbide formers that can optionally be used are vanadium, niobium, zirconium, or a combination thereof.

[0039] The steel has less than about 6.5% titanium. Optionally, the steel can have more than about 0.1% and less than about 6.5% titanium, more than about 0.12% and less than about 6.5% titanium, more than about 0.14% and less than about 6.5% titanium, or more than about 0.2% and less than about 6.5% titanium. If more than 6.5% titanium is used, the steel may not properly form the desired crystalline structure and increases cost without a commensurate improvement in performance.

[0040] In one aspect of the invention, the iron in the steel is at least about 80% by weight.

[0041] In one aspect, less than about 5% of any combination of nickel, manganese, and copper is in the steel (alloy). Optionally, the alloy comprises less than about 0.5%, less than about 1%, less than about 1.5%, less than about 2%, less than about 2.5%, or less than about 3%, of any combination of nickel, manganese and copper. If more than about 5% nickel, manganese, or copper, or combinations thereof, are used to form the steel sheet or plate, the costs unduly increase without a corresponding improvement in performance. Preferably, the steel sheet or plate has substantially no copper

[0042] The boron percentage is important because if the range of about 0.0001% to about 0.01% is not used, the steel will not form martensite when quenched. If more than about 0.01% is used, the steel will be too brittle and can crack in use and it may even be difficult to get the steel out of the caster. The optimum boron range is about 0.002% to about 0.003%.

[0043] The steel alloy includes only small amounts of carbon; at least about 0.003% carbon, and up to about 0.1% carbon. Optionally, the steel comprises less than about 0.05%, less than about 0.04%, less than about 0.03%, less than about 0.02%, or less than about 0.01% carbon.

[0044] Optionally, the steel comprises at least about 0.025% aluminum. Applicant believes the steel forms more intermetallics, thus making the steel stronger.

[0045] The present invention includes a method of making a high strength steel as shown in Figures 1A and 1B. First, as shown in Figure 1A, the steel of the invention comprising iron and carbon is combined in, for example, a vessel (10) with titanium as a strong carbide former, and boron, and poured (20) from the vessel (10) into an ingot or a slab (30). The constituents can be combined in any order or any way so that the result is the combination. Then the combination is heated to a sufficiently high temperature, such as, for example, 1200°C, such that the steel transitions to an austenitic, face centered cubic lattice phase (30) and the titanium removes substantially all of the carbon from the crystal lattice by forming a metal carbide other than iron carbide. Depending on the application, a hot slab (30) can be rolled between rollers (40) to prepare a hot rolled coil or hot rolled plate (50), as shown in Figure 1B. The hot rolled coil or hot rolled plate (50) of alloy steel is quenched to a quench temperature with a quench faster than still air such that a body centered cubic lattice is formed by displacement, and ordered intermetallics are formed in the alloy steel. The hot rolled coil or the hot rolled plate (50) can be coiled (60) after it is rolled. A hot rolled coil or hot rolled plate (50) or coil (60) can be either maintained at temperature or heated to form additional ordered intermetallics. The invention also includes the steel made by the method.

[0046] In another aspect, the present invention is a method of making a steel sheet or plate formed of a martensitic steel alloy. The method comprises the steps of: a) heating the alloy steel to a sufficiently high temperature that the steel transitions to an austenitic, face centered cubic lattice phase and the titanium removes substantially all of the carbon from the crystal lattice by forming a metal carbide other than iron carbide; b) hot rolling the heated alloy steel of step (a); and c) quenching the hot rolled steel of step (b) to a quench temperature with a quench faster than still air such that a body centered cubic lattice is formed by displacement.

[0047] In one aspect, the step of heating comprises heating to a temperature greater than 1000 degree C.

[0048] Optionally, the steel can be cold rolled. In this instance, the method comprises cold rolling the alloy steel to form the sheet or plate before the step of quenching.

[0049] In one aspect, the quench temperature is from about 200 to about 750 degrees C.

[0050] In one aspect, after quenching, the rolled steel is heated to a reheat temperature of between 200 C and 750 C and maintaining it at the reheat temperature for more than one minute. This improves the strength of the steel. In another aspect, the method comprises heating the alloy steel after quenching. In another aspect, the method comprises having the alloy steel at the quench temperature or higher for more than one minute after quenching.

[0051] When being quenched, the temperature has to start above the austenite transition temperature . After the quench, the steel goes from the face centered cubic lattice to the body centered cubic lattice. “Hot” as used in the claims means substantially all face centered cubic lattice; going from face centered cubic lattice to body centered cubic lattice.

[0052] In one aspect, after quenching, the hot rolled steel is maintained at a temperature of greater than 200 degree C for a sufficient time to form order intermetallics.

[0053] Formation of ordered intermetallics in the alloy steel according to the present invention can be done in several ways. The first way is to keep the alloy steel at the same temperature as the temperature in which it was quenched. The second way is to raise the alloy steel above the temperature in which it was quenched. The third way is, after the quench, to allow the alloy steel to cool down, such as with, for example, air cooling, and then reheat, where the reheat temperature is more or less than the quench temperature.

[0054] Optionally, the steel has been hot dip coated in zinc or an alloy containing zinc without substantially recrystallizing the martensitic steel structure. In this instance, the method comprises the additional step of hot dip coating the rolled steel in zinc or an alloy containing zinc without substantially crystallizing the martensitic steel structure.

[0055] In one example, a low carbon alloy steel was made with 1.72% nickel, 0.38% titanium, 0.03% aluminum, 0.0022% boron, 0.021% carbon and 0.34% manganese. The steel was made by reheating the ingots to 1200°C, soaking in air for 1 hour per 25 mm of thickness, and then hot rolled with a finish rolling temperature of between 900°C and 955°C.

[0056] After quenching from about 900°C in water, the low carbon alloy steel of the invention formed an interstitial free martensite structure with a very high dislocation density. This steel is very tough, plastic or viscous-like compared to typical high carbon steels. Typical properties of the steel are:

Tensile	Yield	Total Elongation (TE)
820 MPa	680 MPa	12%

[0057] After cold rolling and aging at 510°C for three hours, the nickel and titanium combined to form very hard, nanometer sized reinforcing rod-like structures with an average diameter of about 4 nm and length of about 15 nm that pin the dislocations and increase the strength of the steel. The titanium also formed additional intermetallic structures with the iron. Typical properties of the steel are:

Tensile	Yield	TE
990 MPa	980 MPa	7%

[0058] The strength, ductility and fracture toughness of the steel can be directly altered as required by the final application by reducing or increasing the amount of each of carbon, nickel, titanium, manganese, and other elements known to one of skill in the art, and changing the time and temperature of the heat treatment(s). The mechanical properties of the steel can also be altered by the order in which they are added to the steel.

[0059] In another example of the invention, an intermediate strength alloy steel was formed with manganese replacing nickel. For this, the material was made up of 1.48% manganese, 0.32% titanium, 0.033% aluminum, 0.0023% boron, 0.039% carbon with the balance iron and normal production and tramp elements.

[0060] In this example, the steel of the invention was made by reheating the ingots to 1200°C, soaking for 1 hour per 25 mm of thickness, and then hot rolled with a finish rolling temperature of between 900°C and 955°C. The hot rolled coil was then quenched from about 900°C in water to about 500°C. The hot rolled coil was then reheated to 500°C and held for 24 hours to simulate a production hot rolling sequence. Average properties of the steel are:

Tensile	Yield	TE
854 MPa	765 MPa	16%

[0061] Other combinations of carbon, nickel, titanium, manganese, intermetallic forming metals and martensite stabilization elements may be used by those skilled in the art.

[0062] In another example, steel was made with 0.003% carbon, 0.3% manganese, 0.12% titanium, and 0.002% boron. The steel was quenched to 200 C.

Tensile	Yield	TE
367 MPa	212 MPa	36%

[0063] In another example, steel was made with 0.15% carbon, 0.3% manganese, 0.14% titanium, and 0.002% boron. The steel was quenched to 200 C.

Tensile	Yield	TE
602 MPa	502 MPa	15%

[0064] In these last two examples, it is demonstrated that more than 0.003% carbon is needed. The system does not work at this carbon level.

[0065] In another example, steel was made with 0.35% carbon, 0.55% manganese, 0.16% titanium, and less than 0.0001% boron. The steel was quenched to 550 C.

Tensile	Yield	TE
444 MPa	383 MPa	30%

[0066] In another example, steel was made with 0.035% carbon, 0.55% manganese, 0.16% titanium, and 0.003% boron. The steel was quenched to 550 C.

Tensile	Yield	TE
684 MPa	593 MPa	14%

[0067] In these last two examples, it is demonstrated that the system only works if boron is present. A key feature is the combination of titanium and boron. The low amounts of nickel, manganese and copper distinguish the invention form a conventional maraging steel. The top limitation(s) on the carbon are to ensure the present invention is not a quenched martensitic low carbon steel. Although the present invention has been described in considerable detail with reference to certain preferred embodiments, other embodiments are possible. The steps disclosed for the present methods, for example, are not intended to be limiting nor are they intended to indicate that each step is necessarily essential to the method, but instead are exemplary steps only. Therefore, the scope of the appended claims should not be limited to the description of preferred embodiments contained in this disclosure.

What is claimed is:

1. A steel sheet or plate formed of a martensitic steel alloy comprising:

a) iron, at least some of the iron having dislocations;

b) less than 5% of any combination of nickel, manganese, and copper;

c) from about 0.0001 to about 0.01% boron;

d) from about 0.05% to about 6.5 % titanium;

e) more than 0.003% and less than 0.1% carbon; and

f) less than 7% of all other elements.

2. The steel sheet or plate of claim 1 wherein the alloy comprises more than 0.1% titanium.

3. The steel sheet or plate of claim 1 wherein the alloy comprises more than 0.12% titanium.

4. The steel sheet or plate of claim 1 wherein the alloy comprises more than 0.14% titanium.

5. The steel sheet or plate of claim 1 wherein the alloy comprises more than 0.2% titanium.

6. The steel sheet or plate of claim 1 wherein the alloy comprises less than 0.5% of any combination of nickel, manganese, and copper.

7. The steel sheet or plate of claim 1 wherein the alloy comprises less than 1% of any combination of nickel, manganese, and copper.

8. The steel sheet or plate of claim 1 wherein the alloy comprises less than 1.5% of any combination of nickel, manganese, and copper.

9. The steel sheet or plate of claim 1 wherein the alloy comprises less than 2% of any combination of nickel, manganese, and copper.

10. The steel sheet or plate of claim 1 wherein the alloy comprises less than 2.5% of any combination of nickel, manganese, and copper.

11. The steel sheet or plate of claim 1 wherein the alloy comprises less than 3% of any combination of nickel, manganese, and copper.

12. The steel sheet or plate of claim 1 wherein the alloy comprises less than 0.05% carbon.

13. The steel sheet or plate of claim 1 wherein the alloy comprises less than 0.04% carbon.

14. The steel sheet or plate of claim 1 wherein the alloy comprises less than 0.03% carbon.

15. The steel sheet or plate of claim 1 wherein the alloy comprises less than 0.02% carbon.

16. The steel sheet or plate of claim 1 wherein the alloy comprises less than 0.01% carbon.

17. The steel sheet or plate of claim 1, wherein the alloy comprises at least 0.025% aluminum.

18. The steel sheet or plate of claim 1 that has been cold rolled.

19. The steel sheet or plate of claim 1, after quenching, that has been reheated to a temperature of between 200 C and 750 C and maintained at that temperature for more than one minute.

20. The steel sheet or plate of claim 1, wherein the alloy is substantially a martensitic structure with minor ferrite zones.

21. The steel sheet or plate of claim 18 that has been hot dip coated in zinc or an alloy containing zinc without substantially crystallizing the martensitic steel structure.

22. The steel sheet or plate of claim 1, wherein the alloy comprises substantially no copper.

23. The steel sheet or plate of claim 1, wherein the alloy has substantially no cementite.

24. A steel sheet or plate formed of a martensitic steel alloy comprising:

a) iron, at least some of the iron having dislocations;

b) less than 5% of any combination of nickel, manganese, and copper;

c) from about 0.0001 to about 0.01% boron;

d) from about 0.05% to about 6.5 % titanium;

e) more than 0.003% and less than 0.1% carbon; and

f) less than 7% of all other elements;

wherein the sheet or plate has been formed by quenching off of a hot sheet or plate mill.

25. The steel sheet or plate of claim 1, wherein the titanium has clustered at the dislocations.

26. A method of making a steel sheet or plate formed of a martensitic steel alloy, the method comprising the steps of:

a) heating the alloy steel defined in claim 1to a sufficiently high temperature that the steel transitions to an austenitic, face centered cubic lattice phase and the titanium removes substantially all of the carbon from the crystal lattice by forming a metal carbide other than iron carbide;

b) hot rolling the heated alloy steel of step (a); and

c) quenching the hot rolled steel of step (b) to a quench temperature with a quench faster than still air such that a body centered cubic lattice is formed by displacement.

27. The method of claim 26 comprising cold rolling the alloy steel to form the sheet or plate before the step of quenching.

28. The method of claim 26 wherein the quench temperature is from about 200 to about 750 degrees C.

29. The method of claim 26 wherein the step of heating comprises heating to a temperature greater than 1000 degree C.

30. The method of claim 26 wherein after quenching the hot rolled steel is maintained at a temperature of greater than 200 degree C for a sufficient time to form order intermetallics.

31. The method of claim 26 wherein, after quenching, heating the rolled steel to a reheat temperature of between 200 C and 750 C and maintaining it at the reheat temperature for more than one minute.

32. The method of claim 26 comprising the additional step of hot dip coating the rolled steel in zinc or an alloy containing zinc without substantially crystallizing the martensitic steel structure.

33. The steel sheet or plate of claim 24 that has been hot dip coated in zinc or an alloy containing zinc without substantially crystallizing the martensitic steel structure.

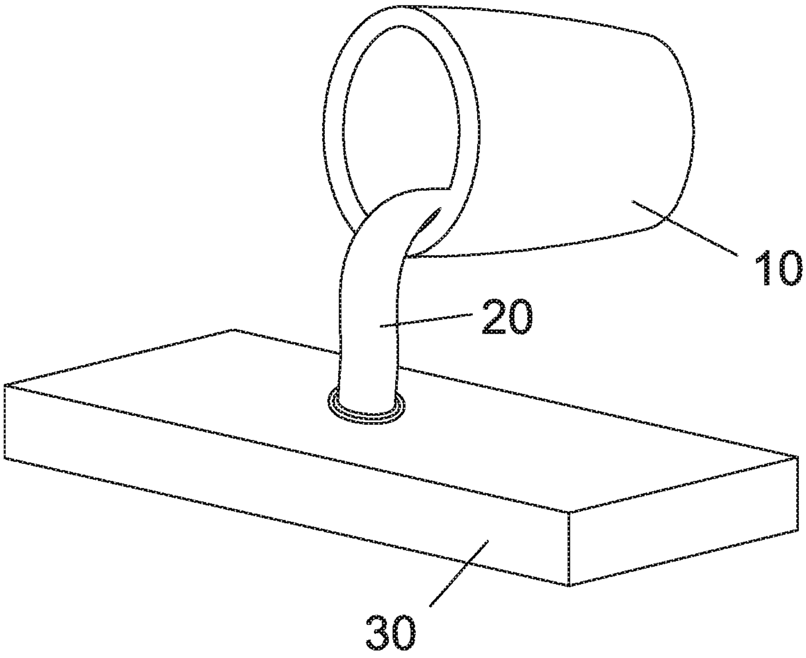

Figure 1A

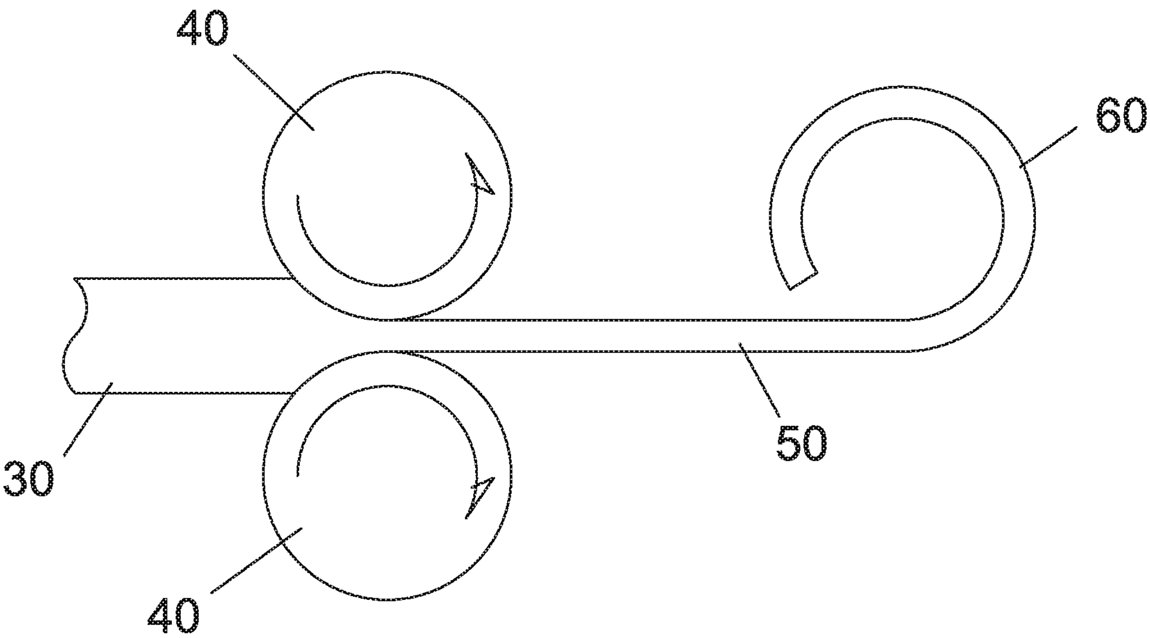

Figure 1B

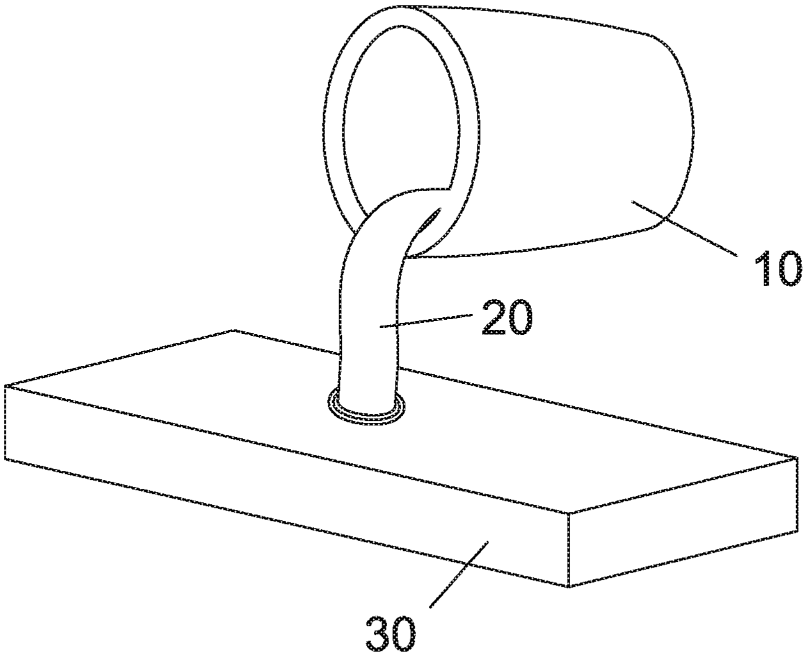

Figure 1A