CLAIMS

We claim:

1. A method of forming a metallic article, the method comprising:

inductively heating a localized region of a metallic article to a forming temperature, wherein the forming temperature is in a forming temperature range of 0.20 to 0.50 of a melting temperature of the material; and

forming the metallic article in the localized region.

2. The method of claim 1, wherein forming the metallic article comprises at least one of bending, drawing, punching, stamping, and roll forming.

3. The method of claim 1, wherein the metallic article comprises a material selected from a titanium alloy, a nickel-base alloy, a stainless steel alloy, a high-strength low-alloy steel, and an armor steel alloy.

4. The method of claim 1, wherein the metallic article is selected from an ingot, a billet, a bloom, a round bar, a square bar, an extrusion, a tube, a pipe, a slab, a sheet, and a plate.

5. The method of claim 1, wherein the metallic article is a plate, the localized region comprises a lineal region, and forming the metallic article comprises bending the metallic article in the lineal region.

6. The method of claim 1, wherein the metallic article comprises a titanium alloy.

7. The method of claim 1, wherein the metallic article comprises a material selected from the group consisting of ASTM Grades 5, 6,12, 19, 20, 21, 23, 24, 25, 29, 32, 35, 36, and 38 titanium alloys.

8. The method of claim 1, wherein the metallic article comprises a specialty steel.

9. The method of claim 1, wherein the metallic article comprises a material selected from a 500 BHN steel armor, a 600 BHN steel armor, a 700 BHN steel armor, a high strength low alloy steel, an RHA alloy, an HHA alloy, and a UHH alloy.

10. The method of claim 1, wherein the metallic article comprises a nickel base alloy.

11. The method of claim 1, wherein metallic article has a thickness of at least 0.125 inches (3.175 mm).

12. The method of claim 1, wherein the metallic article has a thickness of at least 0.1875 inches (4.763 mm).

13. The method of claim 1, wherein the metallic article comprises Ti-4Al-2.5V-1.5Fe-0.25O_2 titanium alloy (UNS 54250) and the forming temperature range is 728°F to 874°F (387°C to 468°C).

14. The method of claim 1, wherein the metallic article comprises a titanium alloy and the forming temperature range is 700°F to 900°F.

15. The method of claim 1, wherein inductively heating the localized region comprises heating the localized region with at least one induction heater to a temperature in the forming temperature range.

16. The method of claim 1, wherein forming the metallic article in the localized region comprises bending the metallic article in the localized region to a radius of at least 2t.

17. The method of claim 1, wherein forming the metallic article in the localized region comprises bending the metallic article in the localized region to a radius of at least 1t.

18. The method of claim 1, wherein after forming, the localized region of the metallic article is free of linear indications and cracks.

19. A method of bending a metallic plate, the method comprising:

inductively heating a lineal region of a metallic plate to a bending temperature, wherein the bending temperature is in a bending temperature range of 0.2 to 0.5 of a melting temperature of the metallic plate; and

bending the metallic plate in the lineal region.

20. The method of claim 19, wherein the metallic plate comprises a material selected from a titanium alloy, a nickel-base alloy, a stainless steel alloy, a high-strength low-alloy steel, and an armor steel alloy.

21. The method of claim 19, wherein the metallic plate comprises a titanium alloy.

22. The method of claim 19, wherein the metallic plate comprises a material selected from the group consisting of ASTM Grades 5, 6,12, 19, 20, 21, 23, 24, 25, 29, 32, 35, 36, and 38 titanium alloys.

23. The method of claim 19, wherein the metallic plate comprises a specialty steel.

24. The method of claim 19, wherein the metallic plate comprises a material selected from a 400 BHN steel armor, a 500 BHN steel armor, a 600 BHN steel armor, a 700 BHN steel armor, a high strength low alloy steel, an RHA alloy, an HHA alloy, and a UHH alloy.

25. The method of claim 19, wherein the metallic plate has a thickness of at least 0.125 inches (3.175 mm).

26. The method of claim 19, wherein the metallic plate has a thickness of at least 0.1875 inches (4.763 mm).

27. The method of claim 19, wherein the metallic plate comprises Ti-4Al-2.5V-1.5Fe-0.25O_2 titanium alloy (UNS 54250) and the bending temperature range is 728°F to 874°F (387°C to 468°C).

28. The method of claim 19, wherein the metallic plate comprises a titanium alloy and the bending temperature range is 700°F to 900°F.

29. The method of claim 19, wherein inductively heating the lineal region comprises heating the lineal region with at least one induction heater to a temperature in the bending temperature range.

30. The method of claim 19, wherein bending the metallic plate in the lineal region comprises bending the metallic plate in the lineal region to a radius of at least 2t.

31. The method of claim 19, wherein bending the metallic plate in the lineal region comprises bending the metallic plate in the lineal region to a radius of at least 1t.

32. The method of claim 19, wherein after forming, the localized region of the metallic article is free of linear indications and cracks.

33. A method of forming a metallic material, the method comprising:

placing a metallic article comprising a material selected from a metal and a metal alloy on a ferrous alloy surface;

inductively heating a localized region of the ferrous alloy surface in contact with a localized region of the metallic article to a predetermined temperature and

thereby conductively heating the localized region of the metallic article to a forming temperature within a forming temperature range; and

forming the metallic article in the localized region of the metallic article.

34. The method of claim 33, wherein the metallic article comprises a material selected from a titanium alloy, a nickel-base alloy, a stainless steel alloy, a high-strength low-alloy steel, and an armor steel alloy.

35. The method of claim 33, wherein the forming temperature range is from 0.2 to 0.5 of a melting temperature of the metallic material.

36. The method of claim 33, wherein the metallic article comprises a titanium alloy.

37. The method of claim 33, wherein the metallic article comprises a material selected from the group consisting of ASTM Grades 5, 6,12, 19, 20, 21, 23, 24, 25, 29, 32, 35, 36, and 38 titanium alloys.

38. The method of claim 33, wherein the metallic article comprises a nickel base alloy.

39. The method of claim 33, wherein the metallic article comprises a specialty steel.

40. The method of claim 33, wherein the metallic article comprises a material selected from a 400 BHN steel armor, a 500 BHN steel armor, a 600 BHN steel armor, a 700 BHN steel armor, a high strength low alloy steel, an RHA alloy, an HHA alloy, and a UHH alloy.

41. The method of claim 33, wherein the metallic article is a plate, the localized region comprises a lineal region, and forming the metallic article in the localized region comprises bending the plate in the lineal region.

42. The method of claim 33, wherein the metallic article has a thickness of at least 0.125 inches (3.175 mm).

43. The method of claim 33, wherein the metallic article has a thickness of at least 0.1875 inches (4.763 mm).

44. The method of claim 33, wherein the metallic article comprises Ti-4Al-2.5V-1.5Fe-0.25O_2 titanium alloy (UNS 54250) and the forming temperature range is 728°F to 874°F (387°C to 468°C).

45. The method of claim 33, wherein the metallic article comprises a titanium alloy and the forming temperature range is 700°F to 900°F

46. The method of claim 33, wherein inductively heating the localized region of the ferrous alloy surface comprises heating the localized region of the ferrous alloy surface with at least one induction heater.

47. The method of claim 33, wherein forming the metallic article in the localized region comprises bending the metallic article in the localized region to a radius of at least 2t.

48. The method of claim 33, wherein forming the metallic article in the localized region comprises bending the metallic article in the localized region to a radius of at least 1t.

49. The method of claim 33, wherein after forming, the localized region is free of linear indications and cracks.

50. The method of claim 33, wherein the metallic article is selected from an ingot, a billet, a bloom, a round bar, a square bar, an extrusion, a tube, a pipe, a slab, a sheet, and a plate.

51. A method of bending a metallic plate, the method comprising:

placing a metallic plate comprising a material selected from a metal and a metal alloy on a ferrous alloy surface;

inductively heating a lineal region of the ferrous alloy surface in contact with a lineal region of the metallic plate to a predetermined temperature and thereby conductively heating the lineal region of the metallic plate to a bending temperature within a bending temperature range; and

bending the metallic plate in the lineal region of the metallic plate.

52. The method of claim 51, wherein the bending temperature range is 0.2 to 0.5 of a melting temperature of the material.

53. The method of claim 51, wherein the metallic plate comprises a material selected from a titanium alloy, a nickel-base alloy, a stainless steel alloy, a high-strength low-alloy steel, and an armor steel alloy.

54. The method of claim 51, wherein the metallic plate comprises a titanium alloy.

55. The method of claim 51, wherein the metallic plate comprises a material selected from the group consisting of ASTM Grades 5, 6,12, 19, 20, 21, 23, 24, 25, 29, 32, 35, 36, and 38 titanium alloys.

56. The method of claim 51, wherein the metallic plate comprises a nickel base alloy.

57. The method of claim 51, wherein the metallic plate comprises a specialty steel.

58. The method of claim 51, wherein the metallic plate comprises a material selected from a 500 BHN steel armor, a 600 BHN steel armor, a 700 BHN armor, a high strength low alloy steel, an RHA alloy, an HHA alloy, and a UHH alloy.

59. The method of claim 51, wherein the metallic plate has a thickness of at least 0.125 inches (3.175 mm).

60. The method of claim 51, wherein the metallic plate has a thickness of at least 0.1875 inches (4.763 mm).

61. The method of claim 51, wherein the metallic plate comprises Ti-4Al-2.5V-1.5Fe-0.25O_2 titanium alloy (UNS R54250) and the bending temperature range is 728°F to 874°F (387°C to 468°C).

62. The method of claim 51, wherein the metallic plate comprises a titanium alloy and the bending temperature range is 700°F to 900°F

63. The method of claim 51, wherein inductively heating the lineal region of the ferrous alloy surface comprises heating the lineal region of the ferrous alloy surface with at least one induction heater.

64. The method of claim 51, wherein bending the metallic plate in the lineal region comprises bending the metallic plate in the lineal region to a bend radius of at least 2t.

65. The method of claim 51, wherein bending the metallic plate along the lineal region comprises bending the metallic plate in the lineal region to a bend radius of at least 1t.

66. The method of claim 51, wherein after bending the lineal region is free of linear indications and cracks.

67. A device for localized heating of a metallic article comprising a material selected from a metal and a metal alloy, the device comprising:

a support including a ferrous alloy surface; and

at least one induction heating device;

wherein the at least one induction heating device is positioned and adapted to inductively heat a localized region of the ferrous alloy surface, and

wherein the inductively heated localized region of the ferrous alloy surface is adapted to heat to a predetermined temperature a localized region of a metallic article comprising a material selected from a metal and a metal alloy that is positioned on the ferrous alloy surface.

68. The device of claim 67, wherein the support comprises at least one of a ferrous alloy sheet including the ferrous alloy surface, and a ferrous alloy plate including the ferrous alloy surface.

69. The device of claim 67, wherein the ferrous alloy surface comprises a steel alloy surface.

70. The device of claim 67, wherein the ferrous alloy surface comprises one or more materials selected from carbon steel, a steel alloy, and a stainless steel.

71. The device of claim 67, wherein the at least one induction heating device is tuned to inductively heat a predetermined localized region of the ferrous alloy surface.

72. The device of claim 67, wherein the at least one induction heating device is positioned opposite the ferrous alloy surface and is adapted to inductively heat a predetermined lineal region of the ferrous alloy surface.

73. A device for localized heating of a metallic article comprising a material selected from a metal and a metal alloy, the device comprising:

a support including a support surface; and

at least one induction heating device;

wherein the at least one induction heating device is positioned and adapted to inductively heat a localized region of metallic article; and positioned on the support surface to a predetermined temperature

wherein the support and the support surface comprise a material that is not heated by the at least one induction heating device.

74. The device of claim 73, wherein the support and support surface comprise a refractory material.

75. The device of claim 73, wherein the support and support surface comprises one or more of aluminum oxide, silicon oxide, aluminosilicate, magnesium oxide, zirconium oxide, calcium oxide, silicon carbide, fire clay, fire brick, magnesite ore, dolomite ore, and chrome ore.

76. The device of claim 73, wherein a frequency of the at least one induction coil is tuned to heat of the material comprising the metallic article.

77. The device of claim 76, wherein the specific metal alloy is a titanium alloy and the frequency of the induction coil is tuned to 1 KHz.

78. A system for bending a metallic article comprising a material selected from a metal and a metal alloy, the system comprising:

a heating device comprising

a support including a ferrous alloy surface, and

at least one induction heating device;

wherein the at least one induction heating device is positioned and adapted to inductively heat a predetermined lineal region of the ferrous alloy surface; and

wherein the inductively heated lineal region of the ferrous alloy surface is adapted to conductively heat a lineal region of a

metallic article positioned on the ferrous alloy surface to a bending temperature in a bending temperature range; and

a metallic material bending apparatus positioned proximate the ferrous alloy surface and adapted to bend the metallic article in the lineal region before the lineal region cools below the bending temperature range.

79. A system for bending a metallic article comprising a material selected from a metal and a metal alloy, the system comprising:

a heating device comprising

a support including a support surface, and

at least one induction heating device;

wherein the at least one induction heating device is positioned and adapted to inductively heat a localized region of metallic article positioned on the support surface to a bending temperature in a bending temperature range; and

wherein the support and the support surface comprise a material that is not heated by the at least one induction heating device; and

a metallic material bending apparatus positioned proximate the support and the support surface and adapted to bend the metallic article in the lineal region before the lineal region cools below the bending temperature range.

80. A formed ballistic armor plate comprising:

at least one of a titanium alloy, a nickel-base alloy, and a specialty steel alloy, a stainless steel alloy, a high-strength low-alloy steel (HSLA), and an armor steel alloy; and

at least one bend region having a bend radius of at least 2t.

81. The formed ballistic armor plate of claim 80, wherein the formed ballistic armor plate has a thickness of at least 0.125 inches (3.175 mm).

82. The formed ballistic armor plate of claim 80, wherein the formed ballistic armor plate has a thickness of at least 0.1875 inches (4.763 mm).

83. The formed ballistic armor plate of claim 80, wherein the formed ballistic armor plate is one of a monolithic hull, a V-shaped hull, a blast protective vehicle underbelly, and an enclosure.

84. An article of manufacture comprising a formed ballistic armor plate according to any of claims 80 through 83.

Claims

1. A method of forming a metallic article, the method comprising:

inductively heating a localized region of a metallic article to a forming temperature, wherein the forming temperature is in a forming temperature range of 0.20 to 0.50 of a melting temperature of the material; and

mechanically forming the metallic article in the localized region, wherein the forming occurs in a single forming step.

2. The method of claim 1, wherein forming the metallic article comprises at least one of bending, drawing, punching, stamping, and roll forming.

3. The method of claim 1, wherein the metallic article comprises a material selected from a titanium alloy, a nickel-base alloy, a stainless steel alloy, a high-strength low-alloy steel, and an armor steel alloy.

4. The method of claim 1, wherein the metallic article is selected from an ingot, a billet, a bloom, a round bar, a square bar, an extrusion, a tube, a pipe, a slab, a sheet, and a plate.

5. The method of claim 1, wherein the metallic article is a plate, the localized region comprises a lineal region, and forming the metallic article comprises bending the metallic article in the lineal region.

6. The method of claim 1, wherein the metallic article comprises a titanium alloy.

7. The method of claim 1, wherein the metallic article comprises a material selected from the group consisting of ASTM Grades 5, 6, 12, 19, 20, 21, 23, 24, 25, 29, 32, 35, 36, and 38 titanium alloys.

8. The method of claim 1, wherein the metallic article comprises a specialty steel.

9. The method of claim 1, wherein the metallic article comprises a material selected from a 500 BHN steel armor, a 600 BHN steel armor, a 700 BHN steel armor, a high strength low alloy steel, an RHA alloy, an HHA alloy, and a UHH alloy.

10. The method of claim 1, wherein the metallic article comprises a nickel base alloy.

11. The method of claim 1, wherein metallic article has a thickness of at least 0.125 inches (3.175 mm).

12. The method of claim 1, wherein the metallic article has a thickness of at least 0.1875 inches (4.763 mm).

13. The method of claim 1, wherein the metallic article comprises Ti-4Al-2.5V-1 .5Fe- 0.25O2 titanium alloy (UNS 54250) and the forming temperature range is 728°F to 874°F (387°C to 468°C).

14. The method of claim 1, wherein the metallic article comprises a titanium alloy and the forming temperature range is 700°F to 900°F.

15. The method of claim 1, wherein inductively heating the localized region comprises heating the localized region with at least one induction heater to a temperature in the forming temperature range.

16. The method of claim 1, wherein forming the metallic article in the localized region comprises bending the metallic article in the localized region to a radius of at least two times a thickness of the metallic article in the localized region.

17. The method of claim 1, wherein forming the metallic article in the localized region comprises bending the metallic article in the localized region to a radius of at least one times a thickness of the metallic article in the localized region.

18. The method of claim 1, wherein after forming, the localized region of the metallic article is free of linear indications and cracks.

19. A method of bending a metallic plate, the method comprising:

inductively heating a lineal region of a metallic plate to a bending temperature, wherein the bending temperature is in a bending temperature range of 0.2 to 0.5 of a melting temperature of the metallic plate; and

mechanically bending the metallic plate in the lineal region, wherein the bending occurs in a single bending step.

20. The method of claim 19, wherein the metallic plate comprises a material selected from a titanium alloy, a nickel-base alloy, a stainless steel alloy, a high-strength low-alloy steel, and an armor steel alloy.

21. The method of claim 19, wherein the metallic plate comprises a titanium alloy.

22. The method of claim 19, wherein the metallic plate comprises a material selected from the group consisting of ASTM Grades 5, 6,12, 19, 20, 21, 23, 24, 25, 29, 32, 35, 36, and 38 titanium alloys.

23. The method of claim 19, wherein the metallic plate comprises a specialty steel.

24. The method of claim 19, wherein the metallic plate comprises a material selected from a 400 BHN steel armor, a 500 BHN steel armor, a 600 BHN steel armor, a 700 BHN steel armor, a high strength low alloy steel, an RHA alloy, an HHA alloy, and a UHH alloy.

25. The method of claim 19, wherein the metallic plate has a thickness of at least 0.125 inches (3.175 mm).

26. The method of claim 19, wherein the metallic plate has a thickness of at least 0.1875 inches (4.763 mm).

27. The method of claim 19, wherein the metallic plate comprises Ti-4Al-2.5V-1 .5Fe- 0.25O2 titanium alloy (UNS 54250) and the bending temperature range is 728°F to 874°F (387°C to 468°C).

28. The method of claim 19, wherein the metallic plate comprises a titanium alloy and the bending temperature range is 700°F to 900°F.

29. The method of claim 19, wherein inductively heating the lineal region comprises heating the lineal region with at least one induction heater to a temperature in the bending temperature range.

30. The method of claim 19, wherein bending the metallic plate in the lineal region comprises bending the metallic plate in the lineal region to a radius of at least two times a thickness of the metallic plate in the lineal region.

31. The method of claim 19, wherein bending the metallic plate in the lineal region comprises bending the metallic plate in the lineal region to a radius of at least one times a thickness of the metallic plate in the lineal region.

32. The method of claim 19, wherein after forming, the localized region of the metallic article is free of linear indications and cracks.

33. A method of forming a metallic material, the method comprising:

placing a metallic article comprising a material selected from a metal and a metal alloy on a ferrous alloy surface;

inductively heating a localized region of the ferrous alloy surface in contact with a localized region of the metallic article to a predetermined temperature and thereby conductively heating the localized region of the metallic article to a forming temperature within a forming temperature range; and

mechanically forming the metallic article in the localized region of the metallic article, wherein the forming occurs in a single forming step.

34. The method of claim 33, wherein the metallic article comprises a material selected from a titanium alloy, a nickel-base alloy, a stainless steel alloy, a high- strength low-alloy steel, and an armor steel alloy.

35. The method of claim 33, wherein the forming temperature range is from 0.2 to 0.5 of a melting temperature of the metallic material.

36. The method of claim 33, wherein the metallic article comprises a titanium alloy.

37. The method of claim 33, wherein the metallic article comprises a material selected from the group consisting of ASTM Grades 5, 6,12, 19, 20, 21, 23, 24, 25, 29, 32, 35, 36, and 38 titanium alloys.

38. The method of claim 33, wherein the metallic article comprises a nickel base alloy.

39. The method of claim 33, wherein the metallic article comprises a specialty steel.

40. The method of claim 33, wherein the metallic article comprises a material selected from a 400 BHN steel armor, a 500 BHN steel armor, a 600 BHN steel armor, a 700 BHN steel armor, a high strength low alloy steel, an RHA alloy, an HHA alloy, and a UHH alloy.

41. The method of claim 33, wherein the metallic article is a plate, the localized region comprises a lineal region, and forming the metallic article in the localized region comprises bending the plate in the lineal region.

42. The method of claim 33, wherein the metallic article has a thickness of at least 0.125 inches (3.175 mm).

43. The method of claim 33, wherein the metallic article has a thickness of at least 0.1875 inches (4.763 mm).

44. The method of claim 33, wherein the metallic article comprises Ti-4Al-2.5V- 1,5Fe-0.25O2 titanium alloy (UNS 54250) and the forming temperature range is 728°F to 874°F (387°C to 468°C).

45. The method of claim 33, wherein the metallic article comprises a titanium alloy and the forming temperature range is 700°F to 900°F.

46. The method of claim 33, wherein inductively heating the localized region of the ferrous alloy surface comprises heating the localized region of the ferrous alloy surface with at least one induction heater.

47. The method of claim 33, wherein forming the metallic article in the localized region comprises bending the metallic article in the localized region to a radius of at least two times a thickness of the metallic article in the localized region.

48. The method of claim 33, wherein forming the metallic article in the localized region comprises bending the metallic article in the localized region to a radius of at least one times a thickness of the metallic article in the localized region.

49. The method of claim 33, wherein after forming, the localized region is free of linear indications and cracks.

50. The method of claim 33, wherein the metallic article is selected from an ingot, a billet, a bloom, a round bar, a square bar, an extrusion, a tube, a pipe, a slab, a sheet, and a plate.

51. A method of bending a metallic plate, the method comprising:

placing a metallic plate comprising a material selected from a metal and a metal alloy on a ferrous alloy surface;

inductively heating a lineal region of the ferrous alloy surface in contact with a lineal region of the metallic plate to a predetermined temperature and thereby conductively heating the lineal region of the metallic plate to a bending temperature within a bending temperature range; and

mechanically bending the metallic plate in the lineal region of the metallic plate, wherein the bending occurs in a single bending step.

52. The method of claim 51, wherein the bending temperature range is 0.2 to 0.5 of a melting temperature of the material.

53. The method of claim 51, wherein the metallic plate comprises a material selected from a titanium alloy, a nickel-base alloy, a stainless steel alloy, a high-strength low-alloy steel, and an armor steel alloy.

54. The method of claim 5, wherein the metallic plate comprises a titanium alloy.

55. The method of claim 51, wherein the metallic plate comprises a material selected from the group consisting of ASTM Grades 5, 6, 12, 19, 20, 21, 23, 24, 25, 29, 32, 35, 36, and 38 titanium alloys.

56. The method of claim 51, wherein the metallic plate comprises a nickel base alloy.

57. The method of claim 51, wherein the metallic plate comprises a specialty steel.

58. The method of claim 51, wherein the metallic plate comprises a material selected from a 500 BHN steel armor, a 600 BHN steel armor, a 700 BHN armor, a high strength low alloy steel, an RHA alloy, an HHA alloy, and a UHH alloy.

59. The method of claim 51, wherein the metallic plate has a thickness of at least 0.125 inches (3.175 mm).

60. The method of claim 51, wherein the metallic plate has a thickness of at least 0.1875 inches (4.763 mm).

61. The method of claim 51, wherein the metallic plate comprises Ti-4Al-2.5V-1,5Fe- 0.25O2 titanium alloy (UNS R54250) and the bending temperature range is 728°F to 874°F (387°C to 468°C).

62. The method of claim 51, wherein the metallic plate comprises a titanium alloy and the bending temperature range is 700°F to 900°F

63. The method of claim 51, wherein inductively heating the lineal region of the ferrous alloy surface comprises heating the lineal region of the ferrous alloy surface with at least one induction heater.

64. The method of claim 51, wherein bending the metallic plate in the lineal region comprises bending the metallic plate in the lineal region to a bend radius of at least two times a thickness of the metallic plate in the lineal region.

65. The method of claim 51, wherein bending the metallic plate along the lineal region comprises bending the metallic plate in the lineal region to a bend radius of at least one times a thickness of the metallic plate in the lineal region.

66. The method of claim 51, wherein after bending the lineal region is free of linear indications and cracks.