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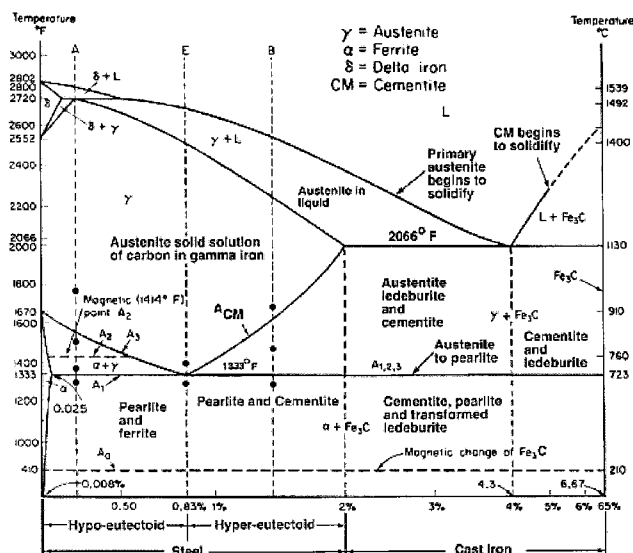


FIG. 1

(57) Abstract: In accordance with the present invention, disclosed herein is a cold rolled steel comprising a continuous sheet of rolled steel rolled to form a plurality of concentric layers, wherein each layer of the plurality of layers is separated a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer, and wherein each separate spacer comprising of a heat resistant material capable of withstanding temperature of at least about 600 °C is present between each adjacent layer. Also disclosed herein, are processes to anneal the continuous sheet of rolled steel exhibiting a reduced carbon footprint.

ANNEALED COLD ROLLED STEEL AND METHOD FOR PREPARING SAME

FIELD OF INVENTION

[0001] This disclosure relates to a cold rolled steel, an annealed cold rolled steel and methods for preparing same.

BACKGROUND

[0002] Steel is a metal alloy comprising iron and carbon that can contribute up to 2.1% of its weight. Carbon, other elements, and inclusions within iron can act as hardening agents that prevent the movement of dislocations that naturally exist in the iron atom crystal lattices. Varying the amount of alloying elements, their form in steel either as solute elements, or as precipitated phases, retards the movement of those dislocations that make iron ductile and weak, and thus, it controls qualities such as the hardness, ductility, and tensile strength of the resulting steel. However, various steel processing steps can also introduce changes in the metal microstructure. For example, when metal is cast, the solidification process results in both macro and micro segregation of the present alloying elements. Often, macro segregation needs to be broken down by mechanical work that in its turn can cause the steel to accumulate stresses and increase steel hardness. The micro segregation cannot be resolved by mechanical work and additional steel treatment is required.

[0003] Annealing is a heat treatment process which is generally performed to reduce hardness, remove residual stresses, improve toughness, restore ductility, and to alter various mechanical, electrical or magnetic properties of the material by refinement of grains in steel microstructure. Annealing can also be performed to homogenize the steel structure to break down micro segregation of the alloying elements in steel and ensure uniform mechanical and electromagnetic properties.

[0004] There are a number of annealing processes common in the steel industry. The general industry practice requires rewinding the cold rolled steel tightly to form large coils before it is transferred for annealing. To achieve a successful outcome of the annealing process, an optimized holding time and temperature, appropriate heating/cooling media and

minimal temperature differences within the structure of heat treated steel are required. However, the current coil setup prevents heat from efficiently reaching the internal strips or layers of coiled steel directly and these inner layers receive the heat only by conduction from the coil surface toward the center of the coil. As a result, these conventional annealing processes are usually slow, highly energy intensive, and can require more than 50 hours to complete. Additionally, the high temperatures and long annealing times required in steel production contribute to already high carbon dioxide emissions by the steel industry (it is estimated that approximately 6.7 % of total world carbon dioxide emission is generated by iron and steel industry).

[0005] Accordingly, there remains a need for an annealed cold rolled steel and methods for preparing same that can provide high quality annealed cold rolled steel while minimizing the total period of time required for a steel heat treatment, reducing carbon footprint, improving cost efficiency, and providing energy consumption savings. These and other needs are satisfied by various aspects of the present disclosure.

SUMMARY OF THE INVENTION

[0006] In accordance with the purposes of the invention, as embodied and broadly described herein, the invention provides a cold rolled steel, comprising: a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers; wherein each layer of the plurality of layers is separated a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer; wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer; and wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature of at least about 600 °C.

[0007] In one exemplary aspect, each separate spacer that is present between each adjacent layer is not a continuous layer.

[0008] In a still further exemplary aspect, the invention relates to an annealed cold rolled steel, comprising: a continuous sheet of annealed rolled steel, wherein the annealed rolled steel forms a plurality of concentric layers; wherein each layer of the plurality of layers is separated a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer; and wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer. In further

aspect, each separate spacer that is present between each adjacent layer is not a continuous layer.

[0009] In further aspects, the invention also relates to a process comprising: a) providing a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers, wherein each layer of the plurality of layers is separated by a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer, wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer, and b) heating the provided continuous sheet of rolled steel to a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel.

[0010] In yet further aspects, disclosed herein is a process comprising: a) providing a continuous sheet of steel; and b) rolling the continuous sheet of steel to form a coil that comprises a plurality of concentric adjacent layers, wherein, during rolling, at least one separate spacer is placed between each adjacent layer of the plurality of layers such that each separate spacer has at least one point of contact with each adjacent layer and such that a gap is formed between each adjacent layer.

[0011] Additional aspects of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or can be learned by practice of the invention. The advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The accompanying figures, which are incorporated in and constitute a part of this specification, illustrate several aspects and together with the description serve to explain the principles of the invention.

[0013] **FIGURE 1** shows a schematic steel phase diagram as a function of temperature, iron weight percent, and carbon weight percent.

[0014] **FIGURE 2** shows a schematic of various steel heat treatments.

[0015] **FIGURE 3** shows a schematic representation of annealing heat treatment steps applied to cold rolled steel.

DETAILED DESCRIPTION

[0016] The present invention can be understood more readily by reference to the following detailed description of the invention.

[0017] Before the present compounds, compositions, articles, systems, devices, and/or methods are disclosed and described, it is to be understood that they are not limited to specific synthetic methods unless otherwise specified, or to particular reagents unless otherwise specified, as such can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, exemplary methods and materials are now described.

[0018] Moreover, it is to be understood that unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is no way intended that an order be inferred, in any respect. This holds for any possible non-express basis for interpretation, including: matters of logic with respect to arrangement of steps or operational flow; plain meaning derived from grammatical organization or punctuation; and the number or type of aspects described in the specification.

[0019] All publications mentioned herein are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited.

A. DEFINITIONS

[0020] It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting. As used in the

specification and in the claims, the term “comprising” can include the aspects “consisting of” and “consisting essentially of.” Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. In this specification and in the claims which follow, reference will be made to a number of terms which shall be defined herein.

[0021] As used in the specification and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a layer” includes the presence of two or more layers.

[0022] As used herein, the term “combination” is inclusive of blends, mixtures, alloys, reaction products, and the like.

[0023] As used herein, the terms “about” and “at or about” mean that the amount or value in question can be the value designated some other value approximately or about the same. It is generally understood, as used herein, that it is the nominal value indicated up to a $\pm 10\%$ variation unless otherwise indicated or inferred. The term is intended to convey that similar values can promote equivalent results or effects recited in the claims. That is, it is understood that amounts, sizes, formulations, parameters, and other quantities and characteristics are not and need not be exact, but can be approximate and/or larger or smaller, as desired, reflecting tolerances, conversion factors, rounding off, measurement error and the like, and other factors known to those of skill in the art. In general, an amount, size, formulation, parameter or other quantity or characteristic is “about” or “approximate” whether or not expressly stated to be such. It is understood that where “about” is used before a quantitative value, the parameter also includes the specific quantitative value itself, unless specifically stated otherwise.

[0024] Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent ‘about,’ it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint. It is also understood that there are a number of values disclosed herein, and that each value is also herein disclosed as “about” that particular value in addition to the value itself. For example, if the value “10” is disclosed, then “about 10” is also disclosed. It is

also understood that each unit between two particular units are also disclosed. For example, if 10 and 15 are disclosed, then 11, 12, 13, and 14 are also disclosed.

[0025] The terms “first,” “second,” “first part,” “second part,” and the like, where used herein, do not denote any order, quantity, or importance, and are used to distinguish one element from another, unless specifically stated otherwise.

[0026] As used herein, the terms “optional” or “optionally” means that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

[0027] As used herein, the term or phrase “effective,” “effective amount,” or “conditions effective to” refers to such amount or condition that is capable of performing the function or property for which an effective amount is expressed. As will be pointed out below, the exact amount or particular condition required will vary from one aspect to another, depending on recognized variables such as the materials employed and the processing conditions observed. However, it should be understood that an appropriate effective amount will be readily determined by one of ordinary skill in the art using only routine experimentation.

[0028] As used herein, the term “rolling” refers to a metal forming process in which metal stock is passed through one or more pairs of rolls to reduce the thickness and to make the thickness uniform.

[0029] As used herein, the term “cold rolled steel” refers to a metal formed during a process in which a steel ingot is cooled to a temperature below the recrystallization temperature of the metal and is forged or rolled into sheets or other shapes. In some aspects, the temperature below recrystallization temperature of the metal can be a room temperature. In other aspects, cold rolling of the steel results in increase of the steel strength via strain hardening up to 20 %. In certain aspects, cold rolling of the steel improves the steel surface finish and holds tighter tolerances. For example and without limitation, common cold-rolled steel products include sheets, strips, bars, and rods. In some aspects, these products can be smaller than similar products produced by processes other than cold rolling. In certain aspects, processing of the cold rolling shapes requires a series of shaping operations, for example and without limitation, sizing, breakdown, roughening, semi-roughening, semi-finishing, and finishing. In some aspects, exemplary uses for cold rolled steel include but are not limited to metal furniture, desks, filing cabinets, shelves, tables, chairs, motorcycle

exhaust pipes, computer cabinets and hardware, home appliances and components, shelving, lighting fixtures, hinges, tubing, steel drums, lawn mowers, electronic housing, lighting fixtures, water heaters, metal containers, and a variety of construction related products.

[0030] As used herein, the term “hot rolled steel” refers to a metal formed during a process in which a steel ingot is kept at a temperature above recrystallization temperature of the metal and is forged or rolled into sheets or other shapes. In some aspects, the metal grains can deform during hot rolling processing. In other aspects, after the deformation the grains can recrystallize. Recrystallization of grains can result in an equiaxed microstructure that can prevent the metal from work hardening. As one of ordinary skill in the art will appreciate, equiaxial grains of equal axial length can have more planes on which to slip and thus can have higher strength and ductility. In certain aspects, the starting material can be large pieces of metal, including exemplary semi-finished casting products, slabs, blooms, or billets. In some aspects, high quality hot rolled steel can have a surface that is covered in mill scale (an oxide forming at high-temperatures). In certain aspects, this oxide layer can be removed via pickling or surface cleaning process, which can reveal a smooth surface. In other aspects, the hot rolling is used to produce sheet metals or simple cross sections, such as rail tracks. Other exemplary uses for hot rolled metal include, but are not limited to, truck frames, automotive wheels, pipes and other tubular articles, water heaters, agriculture equipment, strappings, stampings, compressor shells, railcar components, wheel rims, metal buildings, railroad-hopper cars, doors, shelving, discs, guard rails, and automotive clutch plates.

[0031] As used herein, the terms “pickling” or “pickling bath” can be used interchangeably, and refer to a metal surface treatment used to remove impurities, such as stains, inorganic contaminants, rust or scale from ferrous metals, copper, and aluminum alloys. In some aspects, pickling can be used to descale or clean steel in various steelmaking processes.

[0032] As used herein, the term “predetermined distance” refers to any distance between any two adjacent layers that can be determined by one of ordinary skill in order to achieve a desirable final result. For example and without limitation, in one aspect, the predetermined distance between two adjacent layers can be determined based on the size of an object or spacer to be placed between the two adjacent layers. In another aspect, the predetermined distance can be determined based on the desirable thermal, mechanical or physical outcomes that require separation of the two adjacent layers.

[0033] As used herein, the term “carbon footprint” refers to the total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO₂). In some aspects, a carbon footprint is calculated annually or for a given time period of a year.

[0034] As used herein, the term “substantially identical amount of steel having no gap” refers to a product produced by the substantially identical method as the inventive product by providing essentially the same proportions and components but in the absence of a stated component, for example, in the absence of at least one separate spacer inserted in between any two adjacent layers.

[0035] It is understood that the compositions disclosed herein have certain functions. Disclosed herein are certain structural requirements for performing the disclosed functions and it is understood that there are a variety of structures that can perform the same function that are related to the disclosed structures, and that these structures will typically achieve the same result.

B. STEEL

[0036] As briefly described above, the present disclosure relates, in one aspect, to a cold rolled steel. In one aspect, the cold rolled steel comprises a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers; wherein each layer of the plurality of layers is separated by a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer; wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer; and wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature of at least about 600 °C.

[0037] In another aspect, the continuous sheet of the cold rolled steel is rewound to form a plurality of at least two or more layers. In yet another aspect, the continuous sheet of the cold rolled steel is rewound to form a plurality of at least three or more concentric layer. In a further aspect, the continuous sheet of the cold rolled steel is rewound to form a plurality comprising at least 50, 100, 200, or even 500 layers. In a further aspect, the continuous sheet of the cold rolled steel is rewound to form a coil having an internal diameter about 500 to about 650 mm, including exemplary values of about 505 mm, about 510 mm, about 515 mm, about 520 mm, about 525 mm, about 530 mm, about 535 mm, about 540 mm, about 545 mm,

about 550 mm, about 555 mm, about 560 mm, about 565 mm, about 570 mm, about 575 mm, about 580 mm, about 585 mm, about 590 mm, about 595 mm, about 600 mm, about 605 mm, about 610 mm, about 615 mm, about 620 mm, about 625 mm, about 630 mm, about 635 mm, about 640 mm, and about 645 mm. In still further aspects, the continuous sheet of the cold rolled steel is rewound to form a coil having an internal diameter in any range derived from any two of the above listed exemplary values.

[0038] In one aspect, the continuous sheet of steel has a weight of at least 2 metric tons, at least 3 metric tons, at least 4 metric tons, at least 5 metric tons, at least 6 metric tons, at least 7 metric tons, at least 8 metric tons, at least 9 metric tons, at least 10 metric tons, at least 11 metric tons, at least 12 metric tons, at least 13 metric tons, at least 14 metric tons, at least 15 metric tons, at least 16 metric tons, at least 17 metric tons, at least 18 metric tons, at least 19 metric tons, at least 20 metric tons, at least 21 metric tons, at least 22 metric tons, at least 23 metric tons, at least 24 metric tons, and at least 25 metric tons. In still further aspect, the continuous sheet of the cold rolled steel can be rewound to form a coil having a weight of at least 2 metric tons, at least 3 metric tons, at least 4 metric tons, at least 5 metric tons, at least 6 metric tons, at least 7 metric tons, at least 8 metric tons, at least 9 metric tons, at least 10 metric tons, at least 11 metric tons, at least 12 metric tons, at least 13 metric tons, at least 14 metric tons, at least 15 metric tons, at least 16 metric tons, at least 17 metric tons, at least 18 metric tons, at least 19 metric tons, at least 20 metric tons, at least 21 metric tons, at least 22 metric tons, at least 23 metric tons, at least 24 metric tons, and at least 25 metric tons.

[0039] In one aspect, the cold rolled steel disclosed herein comprises a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers; wherein each layer of the plurality of layers is separated by a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer; and wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer. In one aspect, the rolled steel forms a plurality of at least two or more layers. In yet another aspect, the rolled steel forms a plurality of at least three or more concentric layer. In a further aspect, the rolled steel can form a plurality of up to 50, up to 100, up to 200, or up to 500 layers. In one aspect, the gap formed between each adjacent layer can comprise any gas. In one aspect, the gap can comprise air, nitrogen, hydrogen, or any combination thereof. In another aspect, the gap can comprise air. In yet another aspect, the gap can comprise nitrogen. In still another aspect, the gap can comprise a mixture of air and

nitrogen. In a further aspect, the gap can comprise hydrogen. In a yet further aspect, the gap can comprise a mixture of nitrogen and hydrogen. In a still further aspect, the gap can comprise a mixture of air and hydrogen. In a further aspect, the gap does not comprise oxygen based gases. In certain aspects, the gap can further comprise a noble gas. For example and without limitation, the noble gas can be selected from a group consisting of helium, neon, argon, krypton, xenon, or any combination thereof.

[0040] In one aspect, the predetermined distance between each adjacent layer is in the range from greater than 0 mm to about 5.00 mm, including exemplary values of about 0.1 mm, about 0.2 mm, about 0.3 mm, about 0.4 mm, about 0.5 mm, about 0.6 mm, about 0.7 mm, about 0.8 mm, about 0.9 mm, about 1.0 mm, about 1.1 mm, about 1.2 mm, about 1.3 mm, about 1.4 mm, about 1.5 mm, about 1.6 mm, about 1.7 mm, about 1.8 mm, about 1.9 mm, about 2.0 mm, about 2.1 mm, about 2.2 mm, about 2.3 mm, about 2.4 mm, about 2.5 mm, about 2.6 mm, about 2.7 mm, about 2.8 mm, about 2.9 mm, about 3.0 mm, about 3.1 mm, about 3.2 mm, about 3.3 mm, about 3.4 mm, about 3.5 mm, about 3.6 mm, about 3.7 mm, about 3.8 mm, about 3.9 mm, about 4.0 mm, about 4.1 mm, about 4.2 mm, about 4.3 mm, about 4.4 mm, about 4.5 mm, about 4.6 mm, about 4.7 mm, about 4.8 mm, and about 4.9 mm. In still further aspects, the predetermined distance can be in any range derived from any two of the above listed exemplary values. For example and without limitation, the predetermined distance can be in the range of about 0.5 mm to about 2.5 mm, or about 0.1 mm to about 3.5 mm, or about 2 mm to about 5 mm.

[0041] In one aspect, each separate spacer can comprise any heat resistant material. In another aspect, each separate spacer is capable of withstanding temperature of at least about 600 °C, at least about 650 °C, at least about 700 °C, at least about 750 °C, at least about 800 °C, at least about 850 °C, at least about 900 °C, at least about 950 °C, at least about 1,000 °C, at least about 1,050 °C, at least about 1,100 °C, at least about 1,150 °C, at least about 1,200 °C, at least about 1,250 °C, at least about 1,300 °C, at least about 1,350 °C, at least about 1,400 °C, at least about 1,450 °C, at least about 1,500 °C, at least about 1,550 °C, at least about 1,600 °C, at least about 1,650 °C, at least about 1,700 °C, at least about 1,750 °C, at least about 1,800 °C, at least about 1,850 °C, at least about 1,900 °C, at least about 1,950 °C, and at least about 2,000 °C. In still further aspects, each separate spacer can withhold any temperature in any range derived from any two of the above listed exemplary values.

[0042] In one aspect, the each separate spacer can be comprised of a heat resistant material capable of withstanding temperature in the range of about 600 °C to about 1100 °C, including exemplary values of about 610 °C, about 620 °C, about 630 °C, about 640 °C, about 650 °C, about 660 °C, about 670 °C, about 680 °C, about 690 °C, about 700 °C, about 710 °C, about 720 °C, about 730 °C, about 740 °C, about 750 °C, about 760 °C, about 770 °C, about 780 °C, about 790 °C, about 800 °C, about 810 °C, about 820 °C, about 830 °C, about 840 °C, about 850 °C, about 860 °C, about 870 °C, about 880 °C, about 890 °C, about 900 °C, about 910 °C, about 920 °C, about 930 °C, about 940 °C, about 950 °C, about 960 °C, about 970 °C, about 980 °C, about 990 °C, about 1,000 °C, about 1,010 °C, about 1,020 °C, about 1,030 °C, about 1,040 °C, about 1,050 °C, about 1,060 °C, about 1,070 °C, about 1,080 °C, and about 1,090 °C. In still further aspects, each separate spacer can withhold any temperature in any range derived from any two of the above listed exemplary values. For example, each separate spacer can withhold a temperature in the range of about 600 °C to about 900 °C, or about 700 °C to about 1,100 °C.

[0043] In another aspect, each separate spacer can comprise the same or different heat resistant material. In one aspect, the heat resistant material can comprise a refractory material. In another aspect, each separate spacer can comprise the refractory material. In one aspect, the refractory material is chemically and physically stable in a required range of temperatures. In some aspects, the refractory materials can be chosen according to the conditions that the refractory material needs to be exposed. For example and without limitation, each separate spacer can comprise zirconia. In one aspect, each separate spacer comprises zirconia, for example, in instances when the required range of temperatures is above 1,500 °C. In another aspect, each separate spacer comprises zirconia, for example, when the required range of temperatures is from about 600 °C to about 1,100 °C. In a further aspect, each spacer can comprise silicon carbide, carbon, or a combination thereof. In a yet further aspect, when each separate spacer comprises silicon carbide, carbon, or a combination thereof, each separate spacer is not used in an oxygen containing environment.

[0044] In one aspect, each separate spacer can comprise silica. In yet another aspect, each separate spacer can comprise one or more of alumina, magnesia, lime, tungsten carbide, boron nitride, hafnium carbide, tantalum hafnium carbide, or any combination thereof. In a further aspect, each separate spacer does not comprise metal.

[0045] In one aspect, each separate spacer can be provided in any desired shape or size configured to provide a desired gap between adjacent layers of a coil. In aspects, each separate spacer can be shaped the same or differently. In one aspect, each separate spacer can be disc shaped. In another aspect, each separate spacer can be button shaped. In a further aspect, each separate spacer can have any geometrical form that would allow one of ordinary skill in the art to arrive at the desirable result. For example, and without limitation each separate spacer shape can be circular, cylindrical, tubular, triangular, square, rectangular, rhombic, parallelogram, polygonal, quadrilateral, trapezoid, and such. In one aspect, each separate spacer is not a continuous layer. In yet another aspect, each separate spacer is not a band, a strip or a belt. In a further aspect, each separate spacer is not a web. In a yet further aspect, each separate spacer is not a coating. In one aspect, each separate spacer can be flat. In another aspect, each separate spacer can be curved. In yet another aspect, each separate spacer can have sharp or round corners. In a further aspect, each separate spacer can have a smooth surface. In a yet further aspect, each separate spacer can have a rough surface. In one aspect, each separate spacer can be sufficiently stiff to resist transverse bending of the steel sheet and resulting distortion of the formed coil.

[0046] In one aspect, each separate spacer present between each adjacent layer of the cold rolled steel does not chemically interact with steel to cause any substantial changes in chemical or physical composition of steel and/or each separate spacer.

[0047] In one aspect, each separate spacer can be disc shaped and can have a thickness in the range of about 0.1 mm to about 5.00 mm, including exemplary values of about 0.2 mm, about 0.3 mm, about 0.4 mm, about 0.5 mm, about 0.6 mm, about 0.7 mm, about 0.8 mm, about 0.9 mm, about 1.0 mm, about 1.1 mm, about 1.2 mm, about 1.3 mm, about 1.4 mm, about 1.5 mm, about 1.6 mm, about 1.7 mm, about 1.8 mm, about 1.9 mm, about 2.0 mm, about 2.1 mm, about 2.2 mm, about 2.3 mm, about 2.4 mm, about 2.5 mm, about 2.6 mm, about 2.7 mm, about 2.8 mm, about 2.9 mm, about 3.0 mm, about 3.1 mm, about 3.2 mm, about 3.3 mm, about 3.4 mm, about 3.5 mm, about 3.6 mm, about 3.7 mm, about 3.8 mm, about 3.9 mm, about 4.0 mm, about 4.1 mm, about 4.2 mm, about 4.3 mm, about 4.4 mm, about 4.5 mm, about 4.6 mm, about 4.7 mm, about 4.8 mm, and about 4.9 mm. In still further aspects, each separate spacer can have a thickness in any range derived from any two of the above listed exemplary values. For example and without limitation, each separate spacer can

have a thickness of about 0.5 mm to about 2.5 mm, or about 0.1 mm to about 3.5 mm, or about 2 mm to about 5 mm.

[0048] In another aspect, each separate spacer can be disc shaped and can have a diameter in the range of about 1 to about 25 mm, including exemplary values of about 2 mm, about 3 mm, about 4 mm, about 5 mm, about 6 mm, about 7 mm, about 8 mm, about 9 mm, about 10 mm, about 11 mm, about 12 mm, about 13 mm, about 14 mm, about 15 mm, about 16 mm, about 17 mm, about 18 mm, about 19 mm, about 20 mm, about 21 mm, about 22 mm, about 23 mm, and about 24 mm. In still further aspects, each separate spacer can have a diameter in any range derived from any two of the above listed exemplary values. In one aspect, the diameter can be in the range of about 5 mm to about 15 mm, or about 2 mm to about 17 mm. In one aspect, each separate spacer can have a thickness in the range of about 0.5 mm to about 2.5 mm and a diameter of about 5 mm to about 15 mm.

[0049] In one aspect, each separate spacer can have at least one point of contact with each adjacent layer. In another aspect, each separate spacer can contact each respective adjacent layer at any point of the steel sheet layer. In yet another aspect, each separate spacer can have as many points of contact with each respective adjacent layer as can be determined by the desired shape or geometry of each separate spacer.

[0050] In further aspects, the present disclosure relates to an annealed cold rolled steel. In one aspect, the annealed cold rolled steel comprises: a continuous sheet of annealed rolled steel, wherein the annealed rolled steel forms a plurality of concentric layers; wherein each layer of the plurality of layers is separated a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer; and wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer. In one aspect, the annealed cold rolled steel forms a plurality of at least two or more layers. In yet another aspect, the annealed cold rolled steel forms a plurality of at least three or more concentric layer. In a further aspect, the annealed cold rolled steel can forms a plurality of up to 50, up to 100, up to 200, or up to 500 layers.

[0051] In another aspect, the continuous sheet of annealed cold rolled steel is rewound to form a plurality of at least three or more concentric layer. In yet another aspect, the continuous sheet of annealed cold rolled steel is rewound to form a coil having at least three or more concentric layers. In a further aspect, the continuous sheet of the annealed cold rolled steel is rewound to form a coil having an internal diameter about 500 to about 650 mm,

including exemplary values of about 505 mm, about 510 mm, about 515 mm, about 520 mm, about 525 mm, about 530 mm, about 535 mm, about 540 mm, about 545 mm, about 550 mm, about 555 mm, about 560 mm, about 565 mm, about 570 mm, about 575 mm, about 580 mm, about 585 mm, about 590 mm, about 595 mm, about 600 mm, about 605 mm, about 610 mm, about 615 mm, about 620 mm, about 625 mm, about 630 mm, about 635 mm, about 640 mm, and about 645 mm. In still further aspects, the continuous sheet of annealed cold rolled steel is rewound to form a coil having an internal diameter in any range derived from any two of the above listed exemplary values.

[0052] In another aspect, the continuous sheet of annealed rolled steel has a weight of at least 2 metric tons, at least 3 metric tons, at least 4 metric tons, at least 5 metric tons, at least 6 metric tons, at least 7 metric tons, at least 8 metric tons, at least 9 metric tons, at least 10 metric tons, at least 11 metric tons, at least 12 metric tons, at least 13 metric tons, at least 14 metric tons, at least 15 metric tons, at least 16 metric tons, at least 17 metric tons, at least 18 metric tons, at least 19 metric tons, at least 20 metric tons, at least 21 metric tons, at least 22 metric tons, at least 23 metric tons, at least 24 metric tons, and at least 25 metric tons. In still further aspect, the continuous sheet of annealed rolled steel can be rewound to form a coil having a weight of at least 2 metric tons, at least 3 metric tons, at least 4 metric tons, at least 5 metric tons, at least 6 metric tons, at least 7 metric tons, at least 8 metric tons, at least 9 metric tons, at least 10 metric tons, at least 11 metric tons, at least 12 metric tons, at least 13 metric tons, at least 14 metric tons, at least 15 metric tons, at least 16 metric tons, at least 17 metric tons, at least 18 metric tons, at least 19 metric tons, at least 20 metric tons, at least 21 metric tons, at least 22 metric tons, at least 23 metric tons, at least 24 metric tons, and at least 25 metric tons.

[0053] In one aspect, the annealed cold rolled steel, disclosed herein, comprises a continuous sheet of annealed rolled steel, wherein the annealed rolled steel forms a plurality of concentric layers; wherein each layer of the plurality of layers is separated a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer; and wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer. In one aspect, the annealed cold rolled steel forms a plurality of at least two or more layers. In yet another aspect, the annealed cold rolled steel forms a plurality of at least three or more concentric layers. In a further aspect, the annealed cold rolled steel can form a plurality of up to 50, up to 100, up to 200, or up to 500

layers. In one aspect, the gap formed between each adjacent layer can comprise any gas. In one aspect, the gap can comprise air, nitrogen, hydrogen, or any combination thereof. In another aspect, the gap can comprise air. In yet another aspect, the gap can comprise nitrogen. In still another aspect, the gap can comprise a mixture of air and nitrogen. In a further aspect, the gap can comprise hydrogen. In a yet further aspect, the gap can comprise a mixture of nitrogen and hydrogen. In a still further aspect, the gap can comprise a mixture of air and hydrogen. In a further aspect, the gap does not comprise oxygen based gases. In certain aspects, the gap can further comprise a noble gas. For example and without limitation, the noble gas can be selected from a group consisting of helium, neon, argon, krypton, xenon, or any combination thereof.

[0054] In one aspect, the predetermined distance between each adjacent layer is in the range from greater than 0 mm to about 5.00 mm, including exemplary values of about 0.1 mm, about 0.2 mm, about 0.3 mm, about 0.4 mm, about 0.5 mm, about 0.6 mm, about 0.7 mm, about 0.8 mm, about 0.9 mm, about 1.0 mm, about 1.1 mm, about 1.2 mm, about 1.3 mm, about 1.4 mm, about 1.5 mm, about 1.6 mm, about 1.7 mm, about 1.8 mm, about 1.9 mm, about 2.0 mm, about 2.1 mm, about 2.2 mm, about 2.3 mm, about 2.4 mm, about 2.5 mm, about 2.6 mm, about 2.7 mm, about 2.8 mm, about 2.9 mm, about 3.0 mm, about 3.1 mm, about 3.2 mm, about 3.3 mm, about 3.4 mm, about 3.5 mm, about 3.6 mm, about 3.7 mm, about 3.8 mm, about 3.9 mm, about 4.0 mm, about 4.1 mm, about 4.2 mm, about 4.3 mm, about 4.4 mm, about 4.5 mm, about 4.6 mm, about 4.7 mm, about 4.8 mm, and about 4.9 mm. In still further aspects, the predetermined distance can be in any range derived from any two of the above listed exemplary values. For example and without limitation, the predetermined distance can be in the range of about 0.5 mm to about 2.5 mm, or about 0.1 mm to about 3.5 mm, or about 2 mm to about 5 mm.

[0055] In one aspect, the continuous sheet of annealed rolled steel has been heated to an annealing temperature of at least about 600 °C, at least about 650 °C, at least about 700 °C, at least about 750 °C, at least about 800 °C, at least about 850 °C, at least about 900 °C, at least about 950 °C, at least about 1,000 °C, at least about 1,050 °C, at least about 1,100 °C, at least about 1,150 °C, at least about 1,200 °C, at least about 1,250 °C, at least about 1,300 °C, at least about 1,350 °C, at least about 1,400 °C, at least about 1,450 °C, at least about 1,500 °C, at least about 1,550 °C, at least about 1,600 °C, at least about 1,650 °C, at least about 1,700 °C, at least about 1,750 °C, at least about 1,800 °C, at least about 1,850 °C, at least about

1,900 °C, at least about 1,950 °C, and at least about 2,000 °C. In further aspects, the continuous sheet of annealed rolled steel has been heated to any temperature in any range derived from any two of the above listed exemplary values.

[0056] In one aspect, the annealing temperature is in the range of from at least about 600 °C to about 1,100 °C, including exemplary values of about 610 °C, about 620 °C, about 630 °C, about 640 °C, about 650 °C, about 660 °C, about 670 °C, about 680 °C, about 690 °C, about 700 °C, about 710 °C, about 720 °C, about 730 °C, about 740 °C, about 750 °C, about 760 °C, about 770 °C, about 780 °C, about 790 °C, about 800 °C, about 810 °C, about 820 °C, about 830 °C, about 840 °C, about 850 °C, about 860 °C, about 870 °C, about 880 °C, about 890 °C, about 900 °C, about 910 °C, about 920 °C, about 930 °C, about 940 °C, about 950 °C, about 960 °C, about 970 °C, about 980 °C, about 990 °C, about 1,000 °C, about 1,010 °C, about 1,020 °C, about 1,030 °C, about 1,040 °C, about 1,050 °C, about 1,060 °C, about 1,070 °C, about 1,080 °C, and about 1,090 °C. In further aspects, the annealing temperature can be any temperature in any range derived from any two of the above listed exemplary values. In exemplary aspects, the annealing temperature is in the range of from at least about 600 °C to about 900 °C, or from about 700 °C to about 1,100 °C.

[0057] In certain aspects, each separate spacer comprises a heat resistant material. In some aspects, the heat resistant material can comprise any heat resistant material known in the art. In one aspect, each separate spacer can comprise the same or different any heat resistant material. In yet another aspect, each separate spacer can comprise a refractory material. In one aspect, the refractory materials can be chemically and physically stable in the required range of temperatures. In some aspects, the refractory materials can be chosen according to the conditions the refractory materials are exposed. For example and without limitation, each separate spacer can comprise zirconia. In one aspect, each separate spacer comprises zirconia, for example, in instances when the required range of temperatures is above 1,500 °C. In another aspect, each separate spacer comprises zirconia, for example, when the required range of temperatures is from about 600 °C to about 1,100 °C. In a further aspect, each separate spacer can comprise silicon carbide, carbon, or a combination thereof. In a yet further aspect, when each separate spacer comprises silicon carbide, carbon, or a combination thereof, each separate spacer is not used in an oxygen environment.

[0058] In one aspect, each separate spacer can comprise silica. In yet another aspect, each separate spacer can comprise one or more of alumina, magnesia, lime, tungsten carbide,

boron nitride, hafnium carbide, tantalum hafnium carbide, or any combination thereof. In a further aspect, each separate spacer does not comprise metal.

[0059] In one aspect, each separate spacer can be shaped in any form known in the art. In certain aspect, each separate spacer can be shaped the same or differently. In one aspect, each separate spacer can be disc shaped. In another aspect, each separate spacer can be button shaped. In a further aspect, each separate spacer can have any geometrical form that would allow one of ordinary skill in the art to arrive at the desirable result. For example, and without limitation each separate spacer shape can be circular, cylindrical, tubular, triangular, square, rectangular, rhombic, parallelogram, polygonal, quadrilateral, trapezoid, and like. In one aspect, each separate spacer is not a continuous layer. In yet another aspect, each separate spacer is not a band. In a further aspect, each separate spacer is not a web. In a yet further aspect, each separate spacer is not a coating. In one aspect, each separate spacer can be flat. In another aspect, each separate spacer can be curved. In yet another aspect, each separate spacer can have sharp or round corners. In a further aspect, each separate spacer can have a smooth surface. In a yet further aspect, each separate spacer can have a rough surface. In one aspect, each separate spacer can be sufficiently stiff to resist transverse bending of the steel sheet and resulting distortion of the formed coil.

[0060] In one aspect, each separate spacer present between each adjacent layer of the cold rolled steel does not chemically interact to cause any substantial changes in a chemical or physical composition of steel and/or each separate spacer.

[0061] In one aspect, each separate spacer can have any dimensions allowable by any geometrical form predetermined by one of ordinary skill in the art to arrive at desirable results. In one aspect, each separate spacer when is disc shaped can have a thickness in the range of about 0.1 mm to about 5.00 mm, including exemplary values of about 0.2 mm, about 0.3 mm, about 0.4 mm, about 0.5 mm, about 0.6 mm, about 0.7 mm, about 0.8 mm, about 0.9 mm, about 1.0 mm, about 1.1 mm, about 1.2 mm, about 1.3 mm, about 1.4 mm, about 1.5 mm, about 1.6 mm, about 1.7 mm, about 1.8 mm, about 1.9 mm, about 2.0 mm, about 2.1 mm, about 2.2 mm, about 2.3 mm, about 2.4 mm, about 2.5 mm, about 2.6 mm, about 2.7 mm, about 2.8 mm, about 2.9 mm, about 3.0 mm, about 3.1 mm, about 3.2 mm, about 3.3 mm, about 3.4 mm, about 3.5 mm, about 3.6 mm, about 3.7 mm, about 3.8 mm, about 3.9 mm, about 4.0 mm, about 4.1 mm, about 4.2 mm, about 4.3 mm, about 4.4 mm, about 4.5 mm, about 4.6 mm, about 4.7 mm, about 4.8 mm, and about 4.9 mm. In still further aspects,

each separate spacer can have a thickness in any range derived from any two of the above listed exemplary values. For example and without limitation, each separate spacer can have a thickness of about 0.5 mm to about 2.5 mm, or about 0.1 mm to about 3.5 mm, or about 2 mm to about 5 mm.

[0062] In another aspect, each separate spacer when is disc shaped can have a diameter in the range of about 1 to about 25 mm, including exemplary values of about 2 mm, about 3 mm, about 4 mm, about 5 mm, about 6 mm, about 7 mm, about 8 mm, about 9 mm, about 10 mm, about 11 mm, about 12 mm, about 13 mm, about 14 mm, about 15 mm, about 16 mm, about 17 mm, about 18 mm, about 19 mm, about 20 mm, about 21 mm, about 22 mm, about 23 mm, and about 24 mm. In still further aspects, each separate spacer can have a diameter in any range derived from any two of the above listed exemplary values. In one aspect, the diameter can be in the range of about 5 mm to about 15 mm, or about 2 mm to about 17 mm. In one aspect, each separate spacer can have a thickness in the range of about 0.5 mm to about 2.5 mm and a diameter of about 5 mm to about 15 mm.

[0063] In one aspect, each separate spacer can have at least one point of contact with each adjacent layer. In another aspect, each separate spacer can contact the each adjacent layer at any point of the annealed cold rolled steel sheet. In yet another aspect, each separate spacer can have as many point of contact with each adjacent layer as can be determined by a shape of each separate spacer.

C. PROCESSES

[0064] Also disclosed herein is a process comprising: a) providing a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers, wherein each layer of the plurality of layers is separated by a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer, wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer, and b) heating the provided continuous sheet of rolled steel to a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel. In one aspect, the annealed cold rolled steel forms a plurality of at least two or more layers. In yet another aspect, the annealed cold rolled steel forms a plurality of at least three or more concentric layer. In a further aspect, the annealed cold rolled steel can form a plurality of up to 50, up to 100, up to 200, or up to 500 layers.

[0065] In another aspect, the continuous sheet of the rolled steel is rewound to form a plurality of at least three or more concentric layer. In yet another aspect, the continuous sheet of the rolled steel is rewound to form a coil having a plurality of at least three or more concentric layers. In a further aspect, the continuous sheet of the rolled steel is rewound to form a coil having a plurality of an internal diameter about 500 to about 650 mm, including exemplary values of about 505 mm, about 510 mm, about 515 mm, about 520 mm, about 525 mm, about 530 mm, about 535 mm, about 540 mm, about 545 mm, about 550 mm, about 555 mm, about 560 mm, about 565 mm, about 570 mm, about 575 mm, about 580 mm, about 585 mm, about 590 mm, about 595 mm, about 600 mm, about 605 mm, about 610 mm, about 615 mm, about 620 mm, about 625 mm, about 630 mm, about 635 mm, about 640 mm, and about 645 mm. In still further aspects, the continuous sheet of the rolled steel is rewound to form a coil having an internal diameter in any range derived from any two of the above listed exemplary values.

[0066] In another aspect, the continuous sheet of rolled steel has a weight of at least 2 metric tons, at least 3 metric tons, at least 4 metric tons, at least 5 metric tons, at least 6 metric tons, at least 7 metric tons, at least 8 metric tons, at least 9 metric tons, at least 10 metric tons, at least 11 metric tons, at least 12 metric tons, at least 13 metric tons, at least 14 metric tons, at least 15 metric tons, at least 16 metric tons, at least 17 metric tons, at least 18 metric tons, at least 19 metric tons, at least 20 metric tons, at least 21 metric tons, at least 22 metric tons, at least 23 metric tons, at least 24 metric tons, and at least 25 metric tons. In still further aspect, the continuous sheet of the rolled steel can be rewound to form a coil having a weight of at least 2 metric tons, at least 3 metric tons, at least 4 metric tons, at least 5 metric tons, at least 6 metric tons, at least 7 metric tons, at least 8 metric tons, at least 9 metric tons, at least 10 metric tons, at least 11 metric tons, at least 12 metric tons, at least 13 metric tons, at least 14 metric tons, at least 15 metric tons, at least 16 metric tons, at least 17 metric tons, at least 18 metric tons, at least 19 metric tons, at least 20 metric tons, at least 21 metric tons, at least 22 metric tons, at least 23 metric tons, at least 24 metric tons, and at least 25 metric tons.

[0067] In one aspect, the process, disclosed herein, comprises providing a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers; wherein each layer of the plurality of layers is separated by a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer; and wherein at least one

separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer. In one aspect, the annealed cold rolled steel forms a plurality of at least two or more layers. In yet another aspect, the annealed cold rolled steel forms a plurality of at least three or more concentric layer. In a further aspect, the annealed cold rolled steel can form a plurality of up to 50, up to 100, up to 200, or up to 500 layers. In one aspect, the gap formed between each adjacent layer in this process can comprise any gas. In one aspect, the gap can comprise air, nitrogen, hydrogen, or any combination thereof. In another aspect, the gap can comprise air. In yet another aspect, the gap can comprise nitrogen. In still another aspect, the gap can comprise a mixture of air and nitrogen. In a further aspect, the gap can comprise hydrogen. In a yet further aspect, the gap can comprise a mixture of nitrogen and hydrogen. In a still further aspect, the gap can comprise a mixture of air and hydrogen. In a further aspect, the gap does not comprise oxygen based gases. In certain aspects, the gap can further comprise a noble gas. For example and without limitation, the noble gas can be selected from a group consisting of helium, neon, argon, krypton, xenon, or any combination thereof.

[0068] In one aspect, the predetermined distance between each adjacent layer is in the range from greater than 0 mm to about 5.00 mm, including exemplary values of about 0.1 mm, about 0.2 mm, about 0.3 mm, about 0.4 mm, about 0.5 mm, about 0.6 mm, about 0.7 mm, about 0.8 mm, about 0.9 mm, about 1.0 mm, about 1.1 mm, about 1.2 mm, about 1.3 mm, about 1.4 mm, about 1.5 mm, about 1.6 mm, about 1.7 mm, about 1.8 mm, about 1.9 mm, about 2.0 mm, about 2.1 mm, about 2.2 mm, about 2.3 mm, about 2.4 mm, about 2.5 mm, about 2.6 mm, about 2.7 mm, about 2.8 mm, about 2.9 mm, about 3.0 mm, about 3.1 mm, about 3.2 mm, about 3.3 mm, about 3.4 mm, about 3.5 mm, about 3.6 mm, about 3.7 mm, about 3.8 mm, about 3.9 mm, about 4.0 mm, about 4.1 mm, about 4.2 mm, about 4.3 mm, about 4.4 mm, about 4.5 mm, about 4.6 mm, about 4.7 mm, about 4.8 mm, and about 4.9 mm. In still further aspects, the predetermined distance between each adjacent layer can be in any range derived from any two of the above listed exemplary values. For example and without limitation, the predetermined distance between each adjacent layer can be in the range of about 0.5 mm to about 2.5 mm, or about 0.1 mm to about 3.5 mm, or about 2 mm to about 5 mm.

[0069] In one aspect, each separate spacer can comprise any suitable material determined by one of ordinary skill in the art. In certain aspects, each separate spacer can comprise a heat

resistant material. In another aspect, each separate spacer is capable of withstanding temperature of at least about 600 °C, at least about 650 °C, at least about 700 °C, at least about 750 °C, at least about 800 °C, at least about 850 °C, at least about 900 °C, at least about 950 °C, at least about 1,000 °C, at least about 1,050 °C, at least about 1,100 °C, at least about 1,150 °C, at least about 1,200 °C, at least about 1,250 °C, at least about 1,300 °C, at least about 1,350 °C, at least about 1,400 °C, at least about 1,450 °C, at least about 1,500 °C, at least about 1,550 °C, at least about 1,600 °C, at least about 1,650 °C, at least about 1,700 °C, at least about 1,750 °C, at least about 1,800 °C, at least about 1,850 °C, at least about 1,900 °C, at least about 1,950 °C, and at least about 2,000 °C. In still further aspects, each separate spacer can withhold any temperature in any range derived from any two of the above listed exemplary values.

[0070] In one aspect, each separate spacer can be comprised of a heat resistant material capable of withstanding temperature in the range of about 600 °C to about 1,100 °C, including exemplary values of about 610 °C, about 620 °C, about 630 °C, about 640 °C, about 650 °C, about 660 °C, about 670 °C, about 680 °C, about 690 °C, about 700 °C, about 710 °C, about 720 °C, about 730 °C, about 740 °C, about 750 °C, about 760 °C, about 770 °C, about 780 °C, about 790 °C, about 800 °C, about 810 °C, about 820 °C, about 830 °C, about 840 °C, about 850 °C, about 860 °C, about 870 °C, about 880 °C, about 890 °C, about 900 °C, about 910 °C, about 920 °C, about 930 °C, about 940 °C, about 950 °C, about 960 °C, about 970 °C, about 980 °C, about 990 °C, about 1,000 °C, about 1,010 °C, about 1,020 °C, about 1,030 °C, about 1,040 °C, about 1,050 °C, about 1,060 °C, about 1,070 °C, about 1,080 °C, and about 1,090 °C. In still further aspects, each separate spacer can withhold any temperature in any range derived from any two of the above listed exemplary values. For example, each separate spacer can withhold a temperature in the range about 600 °C to about 900 °C, or about 700 °C to about 1,100 °C.

[0071] In another aspect, each separate spacer can comprise the same or different heat resistant material. In another aspect, each separate spacer can comprise a refractory material. In one aspect, the refractory materials can be chemically and physically stable in the required range of temperatures. In some aspects, the refractory materials can be chosen according to the conditions the refractory materials are exposed. For example and without limitation, each separate spacer can comprise zirconia. In one aspect, each separate spacer comprises zirconia, for example, in instances when the required range of temperatures is above 1,500 °C. In

another aspect, each separate spacer comprises zirconia, for example, when the required range of temperatures is from about 600 °C to about 1,100 °C. In a further aspect, each separate spacer can comprise silicon carbide, carbon, or a combination thereof. In a yet further aspect, when each separate spacer comprises silicon carbide, carbon, or a combination thereof, each separate spacer is not used in an oxygen environment.

[0072] In one aspect, each separate spacer can comprise silica. In yet another aspect, each separate spacer can comprise one or more of alumina, magnesia, lime, tungsten carbide, boron nitride, hafnium carbide, tantalum hafnium carbide, or any combination thereof. In a further aspect, each separate spacer does not comprise metal.

[0073] In one aspect, each separate spacer can be shaped in any form known in the art. In certain aspect, each separate spacer can be shaped the same or differently. In one aspect, each separate spacer can be disc shaped. In another aspect, each separate spacer can be button shaped. In a further aspect, each separate spacer can have any geometrical form that would allow one of ordinary skill in the art to arrive at the desirable result. For example, and without limitation each separate spacer shape can be circular, cylindrical, tubular, triangular, square, rectangular, rhombic, parallelogram, polygonal, quadrilateral, trapezoid, and like. In one aspect, each separate spacer is not a continuous layer. In yet another aspect, each separate spacer is not a band. In a further aspect, each separate spacer is not a web. In a yet further aspect, each separate spacer is not a coating. In one aspect, each separate spacer can be flat. In another aspect, each separate spacer can be curved. In yet another aspect, each separate spacer can have sharp or round corners. In a further aspect, each separate spacer can have a smooth surface. In a yet further aspect, each separate spacer can have a rough surface. In one aspect, each separate spacer can be sufficiently stiff to resist transverse bending of the steel sheet and resulting distortion of the formed coil.

[0074] In one aspect, each separate spacer present between each adjacent layer of the cold rolled steel does not chemically interact to cause any substantial changes in chemical or physical composition of the steel and/or each separate spacer.

[0075] In one aspect, each separate spacer can have any dimensions allowable by any geometrical form predetermined by one of ordinary skill in the art to arrive at desirable results. In one aspect, each separate spacer when is disc shaped can have a thickness in the range of about 0.1 mm to about 5.00 mm, including exemplary values of about 0.2 mm, about 0.3 mm, about 0.4 mm, about 0.5 mm, about 0.6 mm, about 0.7 mm, about 0.8 mm, about 0.9

mm, about 1.0 mm, about 1.1 mm, about 1.2 mm, about 1.3 mm, about 1.4 mm, about 1.5 mm, about 1.6 mm, about 1.7 mm, about 1.8 mm, about 1.9 mm, about 2.0 mm, about 2.1 mm, about 2.2 mm, about 2.3 mm, about 2.4 mm, about 2.5 mm, about 2.6 mm, about 2.7 mm, about 2.8 mm, about 2.9 mm, about 3.0 mm, about 3.1 mm, about 3.2 mm, about 3.3 mm, about 3.4 mm, about 3.5 mm, about 3.6 mm, about 3.7 mm, about 3.8 mm, about 3.9 mm, about 4.0 mm, about 4.1 mm, about 4.2 mm, about 4.3 mm, about 4.4 mm, about 4.5 mm, about 4.6 mm, about 4.7 mm, about 4.8 mm, and about 4.9 mm. In still further aspects, each separate spacer can have a thickness in any range derived from any two of the above listed exemplary values. For example and without limitation, each one separate spacer can have a thickness of about 0.5 mm to about 2.5 mm, or about 0.1 mm to about 3.5 mm, or about 2 mm to about 5 mm.

[0076] In another aspect, each separate spacer when is disc shaped can have a diameter in the range of about 1 to about 25 mm, including exemplary values of about 2 mm, about 3 mm, about 4 mm, about 5 mm, about 6 mm, about 7 mm, about 8 mm, about 9 mm, about 10 mm, about 11 mm, about 12 mm, about 13 mm, about 14 mm, about 15 mm, about 16 mm, about 17 mm, about 18 mm, about 19 mm, about 20 mm, about 21 mm, about 22 mm, about 23 mm, and about 24 mm. In still further aspects, each separate spacer can have a diameter in any range derived from any two of the above listed exemplary values. In one aspect, the diameter can be in the range of about 5 mm to about 15 mm, or about 2 mm to about 17 mm. In one aspect, each separate spacer is disc shaped having a thickness of about 0.5 mm to about 2.5 mm and a diameter in the range of about 5 mm to 15 mm

[0077] In one aspect, each separate spacer can have at least one point of contact with each adjacent layer. In another aspect, each separate spacer can contact the each adjacent layer at any point of the steel sheet. In yet another aspect, each separate spacer can have as many point of contact with each adjacent layer as can be determined by a shape of each separate spacer.

[0078] In one aspect, the provided continuous sheet of rolled steel is heated to a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel. In another aspect, the provided continuous sheet of rolled steel is heated at a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel. In certain aspects, the predetermined temperature is at least about 600 °C, at least about 650 °C, at least about 700 °C, at least about 750 °C, at

least about 800 °C, at least about 850 °C, at least about 900 °C, at least about 950 °C, at least about 1,000 °C, at least about 1,050 °C, at least about 1,100 °C, at least about 1,150 °C, at least about 1,200 °C, at least about 1,250 °C, at least about 1,300 °C, at least about 1,350 °C, at least about 1,400 °C, at least about 1,450 °C, at least about 1,500 °C, at least about 1,550 °C, at least about 1,600 °C, at least about 1,650 °C, at least about 1,700 °C, at least about 1,750 °C, at least about 1,800 °C, at least about 1,850 °C, at least about 1,900 °C, at least about 1,950 °C, and at least about 2,000 °C. In still further aspects, the predetermined temperature is in any range derived from any two of the above listed exemplary values.

[0079] In certain aspects, the provided continuous sheet of rolled steel is heated to anneal the continuous sheet of rolled steel. Annealing is a heat treatment process which is generally performed to reduce hardness, remove residual stress, improve toughness, restore ductility, and to alter various mechanical electrical or magnetic properties of material by refinement of grains in microstructure. There is a number of annealing processes which can be applied to steel.

[0080] As briefly discussed above, steel is an alloy of iron with carbon. FIGURE 1 shows an equilibrium diagram for carbon dissolved in a solid solution of iron. Understanding the carbon-iron diagram is particularly important when a specific heat treatment condition is required. The diagram shows iron and carbon combined to form Fe-Fe₃C with a maximum carbon concentration of about 6.67% C. The steel portion of the equilibrium diagram is defined by carbon present in the range from about 0.008 wt% to about 2.14 wt.% and the eutectoid (E), the hypoeutectoid (A), and the hypereutectoid (B) regions. Carbon is an interstitial impurity in various iron phases. It can form a solid solution with α -iron (α -ferrite), γ -iron (γ -austenite) and δ -iron. The maximum solubility of carbon in ferrite is about 0.022%, wherein the maximum solubility of carbon in austenite is about 2.11%.

[0081] Various annealing heat treatments are shown on FIGURE 2 as a function of an annealing temperature and an amount of carbon present in steel. In certain aspects, the annealing process described herein can comprise a process annealing. The process annealing is a commonly used heat treatment which is designed to treat work-hardened steel of a low carbon content (<0.25% C) and soften steel sufficiently enough to undergo further cold working without fracturing of steel. In some aspects, it can be achieved by changing the size, shape, and redistribution of the grains in microstructure of steel. In further aspects, such microstructural changes are carried out in consecutive stages of recovery, recrystallization

and grain growth. In certain aspects, the process annealing, also known as an intermediate or a subcritical annealing, and is carried out in the ferritic range of steel at any temperatures below steel's austenitizing temperature until any residual stresses have been removed from the lattice structure.

[0082] In other aspects, the annealing process can comprise a normalization annealing process. The normalization annealing process can be applied to ferrous alloys to give the material a uniform fine grained structure and make it less brittle. In some aspects, the normalization annealing process is applied to steel having less than 0.4 % carbon to transform austenite into ferrite, pearlite and sorbite. In certain aspects, the normalization annealing process requires heating the steel to 20-50 °C above steel's critical point. In some aspects, the normalization annealing eliminates columnar grains and dendritic segregation that can occur during casting. Yet, in further aspects, the normalization annealing can improve machinability of a component and provide dimensional stability if the component is subjected to further heat treatment process.

[0083] In yet another aspect, the annealing process can comprise a spheroidizing annealing that is applicable to steels having more than 0.8% carbon. Parts are heated to temperatures of 650-720 °C (below Ferrite-Austenite line (A1), or below the Austenite-Cementite line, FIGURE 2) and hold at this temperature for a period time sufficient to ensure that the microstructural changes are completed. In one aspect, during spheroidizing annealing process cementite phase is transformed to the form of small globules (spheroids) dispersed throughout the ferrite matrix. In certain aspects, the spheroidizing annealing is performed on steel parts that have been work hardened to allow further machining such as coil rolling or wire drawing. In some aspects, spheroidization annealing can also improve steel resistance to abrasion. In certain aspects, the resulting product has improved ductility and toughness with reduced hardness and strength. In some aspects, spheroidizing annealing can be carried out under a protective (endothermic) atmosphere to prevent oxidation and decarburization.

[0084] In certain aspects, the annealing process described herein can comprise full annealing. In one aspect, the full annealing comprises heating carbon steel to about 40 °C above A1 and A3 lines (FIGURE 2). In certain aspects, heating to these temperatures can ensure transformation of the ferrite phase into austenite phase. In other aspects, the cementite phase can continue to exist if the carbon content is greater than about 0.77%. Fully annealed

steel is soft and ductile with no internal stresses, which is often necessary for cost-effective forming.

[0085] In certain aspects, the annealing process described herein can comprise isothermal annealing. In one aspect, isothermal annealing can be performed to produce a pearlite structure, which is a suitable microstructure for cutting and wiredrawing. In some aspects, isothermal annealing can be applied to high alloy steels after hot rolling and cooling, to transform any detrimental structures which may have formed.

[0086] The changes in the steel microstructure take place once steel is heated up to the required holding temperature, annealing temperature, and hold for sufficient time to ensure the microstructural changes are completed. These processes are followed by cooling the steel to room temperature. In some aspects, the annealing heat treatments described herein, commonly occurs in three steps: i) heating; ii) soaking; and iii) cooling. These three steps are shown in FIGURE 3. To achieve a successful and desirable outcome of the annealing process an optimized holding time and temperature, appropriate heating/cooling media, and minimum temperature differences within structure of heat treated steel are required.

[0087] In one aspect, the furnace used for annealing process can be any furnace capable accommodating the three steps of annealing for a selected shape and size of steel. In certain aspects, batch annealing furnaces (BAF) can be used to anneal the provided continuous sheet of rolled steel, wherein the rolled steel forms a plurality of three or more concentric layers. In other aspects, batch annealing furnaces (BAF) can be used to anneal the provided continuous sheet of steel rolled to form a coil that comprises a plurality of there or more concentric layers. In some aspects, the batch annealing furnace can comprise a single-stack batch annealing furnace. In other aspects, the batch annealing furnace can comprise a multi-stack batch annealing furnace.

[0088] In one aspect, the multi-stack batch annealing furnace can be used. In one aspect, the multi-stack batch annealing furnace can comprise about eight batteries, wherein each battery comprises four bases, and wherein each base comprises four stacks of two coils each. In one aspect, the heat source in the multi-stack batch annealing furnace is an electrical heating. In another aspect, the heat media in the multi-stack batch annealing furnace is hydrogen gas.

[0089] In one aspect, the single-stack batch annealing furnace can be used. In one aspect, the single-stack batch annealing furnace is a HICON bell type furnace. In one aspect, the single-stack batch annealing comprises heating about 4 to 6 steel coils, each having substantially identical inner and outer diameters to be stacked on fixed bases with bell type furnace lowered onto the stack. In another aspect, the coil stack is covered with an inner cover. In one aspect, the space between the inner cover and the bell type furnace is heated by a heat source. In one aspect, the heat source is a natural gas. In another aspect, the natural gas is fired into the space between the inner cover and the bell type furnace without contacting the steel coils. In one aspect, burners are located tangentially around the circumference of the furnace.

[0090] In one aspect, to ensure substantially uniform heat distribution inside of the coil and to prevent an oxidation of the coil, a heat media can be circulated inside the cover. In one aspect, the heat media can comprise one or more of hydrogen, nitrogen, air, or any combination thereof. In another aspect, the heat media is hydrogen. In yet another aspect, the heat media is a mixture of hydrogen and nitrogen, wherein the relative amount of each gas in the mixture can be determined by one of ordinary skill in the art. In one aspect, the heat media is circulated by a fan located at the base of the BAF. In one aspect, the fan used to circulate the heat media has a size substantially identical to the inner diameter of the coil. In yet another aspect, the fan used to circulate the heat media has a size of at least about 5 % larger than the inner diameter of the coil, including exemplary values of at least 10% larger, at least 20 % larger, at least 30 % larger, at least 40 % larger, and at least 50 % larger.

[0091] In one aspect, the predetermined temperature is an annealing temperature. In another aspect, the annealing temperature can be any temperature needed to achieve any of the mentioned above annealing processes. In one aspect, the annealing temperature is in the range from about 600 °C to about 900 °C, including exemplary values of about 610 °C, about 620 °C, about 630 °C, about 640 °C, about 650 °C, about 660 °C, about 670 °C, about 680 °C, about 690 °C, about 700 °C, about 710 °C, about 720 °C, about 730 °C, about 740 °C, about 750 °C, about 760 °C, about 770 °C, about 780 °C, about 790 °C, about 800 °C, about 810 °C, about 820 °C, about 830 °C, about 840 °C, about 850 °C, about 860 °C, about 870 °C, about 880 °C, and about 890 °C. In still further aspects, the annealing temperature is in any range derived from any two of the above listed exemplary values.

[0092] In one aspect, the provided continuous sheet of rolled steel is heated for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel. In another aspect, the predetermined period of time is about 5 to about 10 hours, including exemplary values of about 5.5 hours, about 6 hours, about 6.5 hours, about 7 hours, about 7.5 hours, about 8 hours, about 8.5 hours, about 9 hours, and about 9.5 hours. In still further aspects, the predetermined period of time is in any range derived from any two of the above listed exemplary values.

[0093] In one aspect, after the provided continuous sheet of rolled steel is heated to a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel, the heated continuous sheet of rolled steel is cooled back to a second predetermined temperature. In one aspect, to cool the heated continuous sheet of rolled steel the heating bell furnace can be replaced by a cooling bell. In another aspect, the cooling process can comprise, air cooling, water flashing, chilled water cooling, or any combination thereof.

[0094] In one aspect, the heating of the provided continuous sheet of rolled steel to a predetermined temperature for a predetermined period of time and cooling to the second predetermined temperature is performed in a total period of time less than about 40 hours to about 10 hours, including exemplary values of less than about 39 hours, less than about 38 hours, less than about 37 hours, less than about 36 hours, less than about 35 hours, less than about 34 hours, less than about 33 hours, less than about 32 hours, less than about 31 hours, less than about 30 hours, less than about 29 hours, less than about 28 hours, less than about 27 hours, less than about 26 hours, less than about 25 hours, less than about 24 hours, less than about 23 hours, less than about 22 hours, less than about 21 hours, less than about 20 hours, less than about 19 hours, less than about 18 hours, less than about 17 hours, less than about 16 hours, less than about 15 hours, less than about 14 hours, less than about 13 hours, less than about 12 hours, and less than about 11 hours. In still further aspects, the total period of time is in any range derived from any two of the above listed exemplary values.

[0095] The steel industry is known in the art to be one of the industrial emitters of carbon dioxide. Conventional steel making technologies are always energy intensive, where large quantities of fuel are used to provide the needed energy to heat as well as to promote the chemical reactions necessary to produce high quality steel. It is estimated that between 4 and

7 % of the anthropogenic carbon dioxide emissions are actually originated from the steel industry. It is also estimated that the conventional annealing processes require about 1.086 GJ per ton of annealed steel of a direct energy that is defined by the energy use to perform the annealing process. The conventional annealing processes also result in direct emission of about 0.049 ton CO₂ per ton of annealed steel.

[0096] In one aspect, described herein a process providing a more energy efficient solution to reduce carbon footprint as compared to conventional annealing processes. In one aspect, the described process for annealing exhibits a reduced carbon footprint relative to that of a conventional annealing process, wherein a substantially identical amount of steel rolled in a tightly wound configuration having substantially no gap between adjacent layers is heated to the same predetermined temperature. In another aspect, the described process for annealing exhibits a reduced carbon footprint relative to that of a conventional annealing process, wherein a substantially identical amount of steel rolled in a tightly wound configuration having substantially no gap between adjacent layers is heated at the same predetermined temperature. In one aspect, the reduced carbon footprint is at least about a 5 % reduced carbon footprint, at least about a 10 % reduced carbon footprint, at least about a 10 % reduced carbon footprint, at least about a 15 % reduced carbon footprint, at least about a 20 % reduced carbon footprint, at least about a 25 % reduced carbon footprint, at least about a 30 % reduced carbon footprint, at least about a 35 %, at least about 40 %, at least about 45 %, and at least about 50% reduced carbon footprint. In still further aspects, the reduced carbon footprint is in any range derived from any two of the above listed exemplary values.

[0097] In one aspect, the process described herein results in less oxidation of the steel relative to that of a conventional annealing process wherein a substantially identical amount of steel rolled in a tightly wound configuration having substantially no gap between adjacent layers is heated to the same predetermined temperature.

[0098] In various aspects, also described in this invention is a process comprising a) providing a continuous sheet of steel; and b) rolling the continuous sheet of steel to form a coil that comprises a plurality of concentric adjacent layers, wherein during rolling at least one separate spacer is placed between each adjacent layer of the plurality of layer such that each separate spacer has at least one point of contact with each adjacent layer and such that a gap is formed between each adjacent layer. In one aspect, the annealed cold rolled steel forms

a plurality of at least two or more layers. In yet another aspect, the annealed cold rolled steel forms a plurality of at least three or more concentric layer. In a further aspect, the annealed cold rolled steel can form a plurality of up to 50, up to 100, up to 200, or up to 500 layers.

[0099] In one aspect, each one separate spacer can be placed by any means known to one of the ordinary skill in the art. In exemplary aspect, each separate spacer can be placed using a separate feeding equipment. In one aspect, the separate feeding equipment can be installed above the cold rolling processing line. In another aspect, the separate feeding equipment can be installed above the cold rolling processing line and in front of coiling equipment. In one aspect, each separate spacer is fed into coiling system, as the steel sheet is rewound.

[00100] In one aspect, each separate spacer can have at least one point of contact with each adjacent layer. In another aspect, each separate spacer can contact the each respective adjacent layer at any point of the steel sheet layer. In yet another aspect, each separate spacer can have as many points of contact with each respective adjacent layer as can be determined by the desired shape of each separate spacer.

[00101] In one aspect, the gap formed between each adjacent layer can comprise any gas. In one aspect, the gap can comprise air, nitrogen, hydrogen, or any combination thereof. In another aspect, the gap can comprise air. In yet another aspect, the gap can comprise nitrogen. In still another aspect, the gap can comprise a mixture of air and nitrogen. In a further aspect, the gas can comprise hydrogen. In a yet further aspect, the gap can comprise a mixture of nitrogen and hydrogen. In a still further aspect, the gap can comprise a mixture of air and hydrogen. In a further aspect, the gap does not comprise oxygen based gases. In certain aspects, the gap can further comprise a noble gas. For example and without limitation, the noble gas can be selected from a group consisting of helium, neon, argon, krypton, xenon, or any combination thereof.

[00102] In one aspect, each separate spacer can comprise any heat resistant material. In another aspect, each separate spacer is capable of withstanding temperature of at least about 600 °C, at least about 650 °C, at least about 700 °C, at least about 750 °C, at least about 800 °C, at least about 850 °C, at least about 900 °C, at least about 950 °C, at least about 1,000 °C, at least about 1,050 °C, at least about 1,100 °C, at least about 1,150 °C, at least about 1,200 °C, at least about 1,250 °C, at least about 1,300 °C, at least about 1,350 °C, at least about 1,400 °C, at least about 1,450 °C, at least about 1,500 °C, at least about 1,550 °C, at least about 1,600 °C, at least about 1,650 °C, at least about 1,700 °C, at least about 1,750 °C, at

least about 1800 °C, at least about 1,850 °C, at least about 1,900 °C, at least about 1,950 °C, and at least about 2,000 °C. In still further aspects, each separate spacer can withhold any temperature in any range derived from any two of the above listed exemplary values.

[00103] In one aspect, each separate spacer can be comprised of a heat resistant material capable of withstanding temperature in the range of about 600 °C to about 1,100 °C, including exemplary values of about 610 °C, about 620 °C, about 630 °C, about 640 °C, about 650 °C, about 660 °C, about 670 °C, about 680 °C, about 690 °C, about 700 °C, about 710 °C, about 720 °C, about 730 °C, about 740 °C, about 750 °C, about 760 °C, about 770 °C, about 780 °C, about 790 °C, about 800 °C, about 810 °C, about 820 °C, about 830 °C, about 840 °C, about 850 °C, about 860 °C, about 870 °C, about 880 °C, about 890 °C, about 900 °C, about 910 °C, about 920 °C, about 930 °C, about 940 °C, about 950 °C, about 960 °C, about 970 °C, about 980 °C, about 990 °C, about 1,000 °C, about 1,010 °C, about 1,020 °C, about 1,030 °C, about 1,040 °C, about 1,050 °C, about 1,060 °C, about 1,070 °C, about 1,080 °C, and about 1,090 °C. In still further aspects, each separate spacer can withhold any temperature in any range derived from any two of the above listed exemplary values. For example and without limitation, each separate spacer is comprised of a heat resistant material capable of withstanding temperature in the range of about 600 °C to about 900 °C, or about 700 °C to about 1,100 °C.

[00104] In another aspect, each separate spacer can comprise the same or different heat resistant material. In another aspect, each separate spacer can comprise a refractory material. In one aspect, the refractory materials can be chemically and physically stable in a required range of temperatures. In some aspects, the refractory materials can be chosen according to the conditions the refractory materials are exposed. For example and without limitation, each separate spacer can comprise zirconia. In one aspect, each separate spacer comprises zirconia, for example, in instances when the required range of temperatures is above 1,500 °C. In another aspect, each separate spacer comprises zirconia, for example, when the required range of temperatures is from about 600 °C to about 900 °C. In a further aspect, each separate spacer can comprise silicon carbide, carbon, or a combination thereof. In a yet further aspect, when each separate spacer comprises silicon carbide, carbon, or a combination thereof, each separate spacer is not used in an oxygen environment.

[00105] In one aspect, each separate spacer can comprise silica. In yet another aspect, each separate spacer can comprise one or more of alumina, magnesia, lime, tungsten carbide,

boron nitride, hafnium carbide, tantalum hafnium carbide, or any combination thereof. In a further aspect, each separate spacer does not comprise metal.

[00106] In one aspect, each one separate spacer can be shaped in any form known in the art. In certain aspect, each separate spacer can be shaped the same or differently. In one aspect, each separate spacer can be disc shaped. In another aspect, each separate spacer can be button shaped. In a further aspect, each separate spacer can have any geometrical form that would allow one of ordinary skill in the art to arrive at the desirable result. For example, and without limitation each separate spacer shape can be circular, cylindrical, tubular, triangular, square, rectangular, rhombic, parallelogram, polygonal, quadrilateral, trapezoid, and like. In one aspect, each separate spacer is not a continuous layer. In yet another aspect, each separate spacer is not a band. In a further aspect, each separate spacer is not a web. In a yet further aspect, each separate spacer is not a coating. In one aspect, each separate spacer can be flat. In another aspect, each separate spacer can be curved. In yet another aspect, each separate spacer can have sharp or round corners. In a further aspect, each separate spacer can have a smooth surface. In a yet further aspect, each separate spacer can have a rough surface. In one aspect, each separate spacer can be sufficiently stiff to resist transverse bending of the steel sheet and resulting distortion of the formed coil.

[00107] In one aspect, each separate spacer present between each adjacent layer of the cold rolled steel does not interact with the steel chemically to cause any substantial changes in chemical or physical composition of the steel and/or each separate spacer.

[00108] In one aspect, each separate spacer can have any dimensions allowable by any geometrical form predetermined by one of ordinary skill in the art to arrive at desirable results. In one aspect, each separate spacer when is disc shaped can have a thickness in the range of about 0.1 mm to about 5.00 mm, including exemplary values of about 0.2 mm, about 0.3 mm, about 0.4 mm, about 0.5 mm, about 0.6 mm, about 0.7 mm, about 0.8 mm, about 0.9 mm, about 1.0 mm, about 1.1 mm, about 1.2 mm, about 1.3 mm, about 1.4 mm, about 1.5 mm, about 1.6 mm, about 1.7 mm, about 1.8 mm, about 1.9 mm, about 2.0 mm, about 2.1 mm, about 2.2 mm, about 2.3 mm, about 2.4 mm, about 2.5 mm, about 2.6 mm, about 2.7 mm, about 2.8 mm, about 2.9 mm, about 3.0 mm, about 3.1 mm, about 3.2 mm, about 3.3 mm, about 3.4 mm, about 3.5 mm, about 3.6 mm, about 3.7 mm, about 3.8 mm, about 3.9 mm, about 4.0 mm, about 4.1 mm, about 4.2 mm, about 4.3 mm, about 4.4 mm, about 4.5 mm, about 4.6 mm, about 4.7 mm, about 4.8 mm, and about 4.9 mm. In still further aspects,

each separate spacer can have a thickness in any range derived from any two of the above listed exemplary values. For example and without limitation, each separate spacer can have a thickness of about 0.5 mm to about 2.5 mm, or about 0.1 mm to about 3.5 mm, or about 2 mm to about 5 mm.

[00109] In another aspect, each separate spacer when is disc shaped can have a diameter in the range of about 1 to about 25 mm, including exemplary values of about 2 mm, about 3 mm, about 4 mm, about 5 mm, about 6 mm, about 7 mm, about 8 mm, about 9 mm, about 10 mm, about 11 mm, about 12 mm, about 13 mm, about 14 mm, about 15 mm, about 16 mm, about 17 mm, about 18 mm, about 19 mm, about 20 mm, about 21 mm, about 22 mm, about 23 mm, and about 24 mm. In still further aspects, each separate spacer can have a diameter in any range derived from any two of the above listed exemplary values. In one aspect, the diameter can be in the range of about 5 mm to about 15 mm, or about 2 mm to about 17 mm. In one aspect, each separate spacer can have a thickness in the range of about 0.5 mm to about 2.5 mm and a diameter of about 5 mm to about 15 mm.

[00110] In various aspects of this invention, once the rolled continuous sheet of steel is coiled, the coil with each separate spacer placed between each adjacent layer of the plurality of layers is tightened. In one aspect, the continuous sheet of the cold rolled steel is tightened to form a coil having an internal diameter about 500 to about 650 mm, including exemplary values of about 505 mm, about 510 mm, about 515 mm, about 520 mm, about 525 mm, about 530 mm, about 535 mm, about 540 mm, about 545 mm, about 550 mm, about 555 mm, about 560 mm, about 565 mm, about 570 mm, about 575 mm, about 580 mm, about 585 mm, about 590 mm, about 595 mm, about 600 mm, about 605 mm, about 610 mm, about 615 mm, about 620 mm, about 625 mm, about 630 mm, about 635 mm, about 640 mm, and about 645 mm. In still further aspects, the continuous sheet of the cold rolled steel is rewound to form a coil having an internal diameter in any range derived from any two of the above listed exemplary values.

[00111] In another aspect, the continuous sheet of steel has a weight of at least 2 metric tons, at least 3 metric tons, at least 4 metric tons, at least 5 metric tons, at least 6 metric tons, at least 7 metric tons, at least 8 metric tons, at least 9 metric tons, at least 10 metric tons, at least 11 metric tons, at least 12 metric tons, at least 13 metric tons, at least 14 metric tons, at least 15 metric tons, at least 16 metric tons, at least 17 metric tons, at least 18 metric tons, at least 19 metric tons, at least 20 metric tons, at least 21 metric tons, at least 22 metric tons, at

least 23 metric tons, at least 24 metric tons, and at least 25 metric tons. In still further aspect, the continuous sheet of the cold rolled steel can be rewound to form a coil having a weight of at least 2 metric tons, at least 3 metric tons, at least 4 metric tons, at least 5 metric tons, at least 6 metric tons, at least 7 metric tons, at least 8 metric tons, at least 9 metric tons, at least 10 metric tons, at least 11 metric tons, at least 12 metric tons, at least 13 metric tons, at least 14 metric tons, at least 15 metric tons, at least 16 metric tons, at least 17 metric tons, at least 18 metric tons, at least 19 metric tons, at least 20 metric tons, at least 21 metric tons, at least 22 metric tons, at least 23 metric tons, at least 24 metric tons, and at least 25 metric tons.

[00112] In certain aspects, the tightened coil is transferred for annealing heat treatment. In one aspect, the rolled continuous sheet of steel coiled into the coil is heated to a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel.

[00113] In certain aspects, each separate spacer is removed from the coil after completion of the annealing process. In some aspects, a recoiling process can be performed on the annealed coil. In one aspect, the coil can be opened to remove each separate spacer. In various aspects, each separate spacer can be removed by means of an air knife nozzle. In another aspect, each separate spacer can be removed by any means known to one of ordinary skill in the art.

[00114] In some aspects of this invention, after the recoiling process is completed each separate spacer can be collected and fed back into the feeding equipment.

D. ASPECTS

[00115] In various aspects, the present invention pertains to and includes at least the following aspects.

[00116] Aspect 1: A cold rolled steel, comprising: a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers; wherein each layer of the plurality of layers is separated by a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer; wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer,

and wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature of at least about 600 °C.

[00117] Aspect 2: The cold rolled steel of Aspect 1, wherein each separate spacer is not a continuous layer.

[00118] Aspect 3: The cold rolled steel of any one of Aspects 1-2, wherein the predetermined distance between each adjacent layer is in the range of from about 0.5 mm to 2.5 mm.

[00119] Aspect 4: The cold rolled steel of any one of Aspects 1-3, wherein each separate spacer comprises silica.

[00120] Aspect 5: The cold rolled steel of any one of Aspects 1-4, wherein each separate spacer is disc shaped.

[00121] Aspect 6: The cold rolled steel of any one of Aspects 1-5, wherein each separate spacer is disc shaped having a thickness in the range of about 0.5 to 2.5 mm and a diameter in the range of about 5 to 10 mm.

[00122] Aspect 7: The cold rolled steel of any one of Aspects 1-6, wherein the continuous sheet of steel has a weight of at least about 2 metric tons.

[00123] Aspect 8: The cold rolled steel of any one of Aspects 1-7, wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature in the range of about 600 °C to about 900 °C.

[00124] Aspect 9: An annealed cold rolled steel, comprising: a continuous sheet of annealed rolled steel, wherein the annealed rolled steel forms a plurality concentric layers; wherein each layer of the plurality of layers is separated by a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer, and wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer.

[00125] Aspect 10: The annealed cold rolled steel of Aspect 9, wherein each separate spacer is not a continuous layer.

[00126] Aspect 11: The annealed cold rolled steel of any one of Aspects 9-10, wherein the continuous sheet of annealed rolled steel has been heated to an annealing temperature of at least about 600 °C.

[00127] Aspect 12: The annealed cold rolled steel of any one of Aspects 9-11, wherein the annealing temperature is in the range of from at least about 600 °C to about 900 °C.

[00128] Aspect 13: The annealed cold rolled steel of any one of Aspects 9-12, wherein the predetermined distance between each adjacent layer is in the range of from about 0.5 mm to 2.5 mm.

[00129] Aspect 14: The annealed cold rolled steel of any one of Aspects 9-13, wherein each separate spacer is comprised of silica.

[00130] Aspect 15: The annealed cold rolled steel of any one of Aspects 9-14, wherein each separate spacer is disc shaped.

[00131] Aspect 16: The annealed cold rolled steel of any one of Aspects 9-15, wherein each separate spacer is disc shaped having a thickness in the range of about 0.5 to 2.5 mm and a diameter in the range of about 5 to 10 mm.

[00132] Aspect 17: The annealed cold rolled steel of any one of Aspects 9-16, wherein the continuous sheet of anneal rolled steel has a weight of at least about 2 metric tons.

[00133] Aspect 18: A process comprising: a) providing a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers, wherein each layer of the plurality of layers is separated a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer, wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer, and b) heating the provided continuous sheet of rolled steel to a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel.

[00134] Aspect 19: The process of Aspect 18, wherein the predetermined distance between each adjacent layer is in the range of from about 0.5 mm to 2.5 mm.

[00135] Aspect 20: The process of any one of Aspects 18-19, wherein each separate spacer is not a continuous layer.

[00136] Aspect 21: The process of any one of Aspects 18-20, wherein each separate spacer comprises silica.

[00137] Aspect 22: The process of any one of Aspects 18-21, wherein each separate spacer is disc shaped.

[00138] Aspect 23: The process of any one of Aspects 18-22, wherein each separate spacer is disc shaped having a thickness in the range of about 0.5 to 2.5 mm and a diameter in the range of about 5 to 10 mm.

[00139] Aspect 24: The process of any one of Aspects 18-23, wherein the continuous sheet of steel has a weight of at least about 2 metric tons.

[00140] Aspect 25: The process of any one of Aspects 18-24, wherein the predetermined period of time is about 5 to 10 hours.

[00141] Aspect 26: The process of any one of Aspects 18-25, wherein the predetermined temperature is at least about 600 °C.

[00142] Aspect 27: The process of any one of Aspects 18-26, wherein the predetermined temperature is an annealing temperature in the range from about 600 °C to about 900 °C.

[00143] Aspect 28: The process of any one of Aspects 18-27, wherein after the provided continuous sheet of rolled steel is heated for the predetermined period of time the heated system is cooled back to a second predetermined temperature.

[00144] Aspect 29: The process of any one of Aspects 18-28, wherein heating the provided continuous sheet of rolled steel to the predetermined temperature for the predetermined time and cooling to the second predetermined temperature is performed in a total period of time less than about 20 hours.

[00145] Aspect 30: The process of any one of Aspects 18-29, wherein the process for annealing exhibits a reduced carbon footprint relative to that of a conventional annealing process wherein a substantially identical amount of steel rolled in a tightly wound configuration having no gap between adjacent layers is heated to the same predetermined temperature.

[00146] Aspect 31: The process of any one of Aspects 18-30, wherein the reduced carbon footprint is at least a 35% reduced carbon footprint.

[00147] Aspect 32: A process, comprising: a) providing a continuous sheet of steel; and b) rolling the continuous sheet of steel to form a coil that comprises a plurality of concentric adjacent layers, wherein during rolling at least one separate spacer is placed between each adjacent layer of the plurality of layers such that each separate spacer has at least one point of contact with each adjacent layer and such that a gap is formed between each adjacent layer.

[00148] Aspect 33: The process of Aspect 32, wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature of at least about 600 °C.

[00149] Aspect 34: The process of any one of Aspects 32-33, wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature in the range of about 600 °C to about 900 °C.

[00150] Aspect 35: The process of any one of Aspects 32-34, further comprising heating the rolled continuous sheet of steel to a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel.

[00151] Aspect 36: The process of any one of Aspects 32-35, wherein each separate spacer is not a continuous layer.

[00152] Aspect 37: The process of any one of Aspects 32-36, wherein the predetermined distance between each adjacent layer is in the range of from about 0.5 mm to 2.5 mm.

[00153] Aspect 38: The process of any one of Aspects 32-37, wherein each separate spacer comprises silica.

[00154] Aspect 39: The process of any one of Aspects 32-38, wherein each separate spacer is disc shaped.

[00155] Aspect 40: The process of any one of Aspects 32-39, wherein each separate spacer is disc shaped having a thickness in the range of about 0.5 to 2.5 mm and a diameter in the range of about 5 to 10 mm.

[00156] Aspect 41: The process of any one of Aspects 32-40, wherein the continuous sheet of steel has a weight of at least about 2 metric tons.

[00157] Without further elaboration, it is believed that one skilled in the art can, using the description herein, utilize the present invention. The following examples are included to provide addition guidance to those skilled in the art of practicing the claimed invention. The examples provided are merely representative of the work and contribute to the teaching of the present invention. Accordingly, these examples are not intended to limit the invention in any manner.

[00158] Throughout this application, various publications are referenced. The disclosures of these publications in their entireties are hereby incorporated by reference into this application in order to more fully describe the state of the art to which this pertains. The

references disclosed are also individually and specifically incorporated by reference herein for the material contained in them that is discussed in the sentence in which the reference is relied upon. Nothing herein is to be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided herein can be different from the actual publication dates, which can require independent confirmation.

CLAIMS

What is claimed is:

1. A cold rolled steel, comprising:
 - a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers;
 - wherein each layer of the plurality of layers is separated by a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer;
 - wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer, and
 - wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature of at least about 600 °C.
2. The cold rolled steel of claim 1, wherein each separate spacer is not a continuous layer.
3. The cold rolled steel of claim 1, wherein the predetermined distance between each adjacent layer is in the range of from about 0.5 mm to 2.5 mm.
4. The cold rolled steel of claim 1, wherein each separate spacer comprises silica.
5. The cold rolled steel of claim 1, wherein each separate spacer is disc shaped.
6. The cold rolled steel of claim 1, wherein each separate spacer is disc shaped having a thickness in the range of about 0.5 to 2.5 mm and a diameter in the range of about 5 to 10 mm.
7. The cold rolled steel of claim 1, wherein the continuous sheet of steel has a weight of at least about 10 metric tons.
8. The cold rolled steel of claim 1, wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature in the range of about 600 °C to about 900 °C.
9. An annealed cold rolled steel, comprising:
 - a continuous sheet of annealed rolled steel, wherein the annealed rolled steel forms a plurality concentric layers;
 - wherein each layer of the plurality of layers is separated by a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer, and

wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer.

10. The annealed cold rolled steel of claim 9, wherein each separate spacer is not a continuous layer.
11. The annealed cold rolled steel of claim 9, wherein the continuous sheet of annealed rolled steel has been heated to an annealing temperature of at least about 600 °C.
12. The annealed cold rolled steel of claim 11, wherein the annealing temperature is in the range of from at least about 600 °C to about 900 °C.
13. The annealed cold rolled steel of claim 9, wherein the predetermined distance between each adjacent layer is in the range of from about 0.5 mm to 2.5 mm.
14. The annealed cold rolled steel of claim 9, wherein each separate spacer is comprised of silica.
15. The annealed cold rolled steel of claim 9, wherein each separate spacer is disc shaped.
16. The annealed cold rolled steel of claim 9, wherein each separate spacer is disc shaped having a thickness in the range of about 0.5 to 2.5 mm and a diameter in the range of about 5 to 10 mm.
17. The annealed cold rolled steel of claim 9, wherein the continuous sheet of annealed rolled steel has a weight of at least about 10 metric tons.
18. A process comprising:
 - a) providing a continuous sheet of rolled steel, wherein the rolled steel forms a plurality of concentric layers, wherein each layer of the plurality of layers is separated a predetermined distance from each adjacent layer such that a gap is formed between each adjacent layer, wherein at least one separate spacer is present between each adjacent layer and has at least one point of contact with each adjacent layer, and
 - b) heating the provided continuous sheet of rolled steel to a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel.
19. The process of claim 18, wherein the predetermined distance between each adjacent layer is in the range of from about 0.5 mm to 2.5 mm.
20. The process of claim 18, wherein each separate spacer is not a continuous layer.
21. The process of claim 18, wherein each separate spacer comprises silica.
22. The process of claim 18, wherein each separate spacer is disc shaped.

23. The process of claim 18, wherein each separate spacer is disc shaped having a thickness in the range of about 0.5 to 2.5 mm and a diameter in the range of about 5 to 10 mm.
24. The process of claim 18, wherein the continuous sheet of steel has a weight of at least about 10 metric tons.
25. The process of claim 18, wherein the predetermined period of time is about 5 to 10 hours.
26. The process of claim 18, wherein the predetermined temperature is at least about 600 °C.
27. The process of claim 18, wherein the predetermined temperature is an annealing temperature in the range from about 600 °C to about 900 °C.
28. The process of claim 18, wherein after the provided continuous sheet of rolled steel is heated for the predetermined period of time the heated system is cooled back to a second predetermined temperature.
29. The process of claim 28, wherein heating the provided continuous sheet of rolled steel to the predetermined temperature for the predetermined time and cooling to the second predetermined temperature is performed in a total period of time less than about 20 hours.
30. The process of any of claims 18-29, wherein the process for annealing exhibits a reduced carbon footprint relative to that of a conventional annealing process wherein a substantially identical amount of steel rolled in a tightly wound configuration having no gap between adjacent layers is heated to the same predetermined temperature.
31. The process of claim 30, wherein the reduced carbon footprint is at least a 35% reduced carbon footprint.
32. A process, comprising:
 - a) providing a continuous sheet of steel; and
 - b) rolling the continuous sheet of steel to form a coil that comprises a plurality of concentric adjacent layers, wherein during rolling at least one separate spacer is placed between each adjacent layer of the plurality of layers such that each separate spacer has at least one point of contact with each adjacent layer and such that a gap is formed between each adjacent layer.
33. The process of claim 32, wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature of at least about 600 °C.

34. The process of claim 33, wherein each separate spacer is comprised of a heat resistant material capable of withstanding temperature in the range of about 600 °C to about 900 °C.
35. The process of claim 32, further comprising heating the rolled continuous sheet of steel to a predetermined temperature for a predetermined period of time sufficient to anneal the continuous sheet of rolled steel.
36. The process of claim 32, wherein each separate spacer is not a continuous layer.
37. The process of claim 32, wherein the predetermined distance between each adjacent layer is in the range of from about 0.5 mm to 2.5 mm.
38. The process of claim 32, wherein each separate spacer comprises silica.
39. The process of claim 32, wherein each separate spacer is disc shaped.
40. The process of claim 32, wherein each separate spacer is disc shaped having a thickness in the range of about 0.5 to 2.5 mm and a diameter in the range of about 5 to 10 mm.
41. The process of claim 32, wherein the continuous sheet of steel has a weight of at least about 10 metric tons.

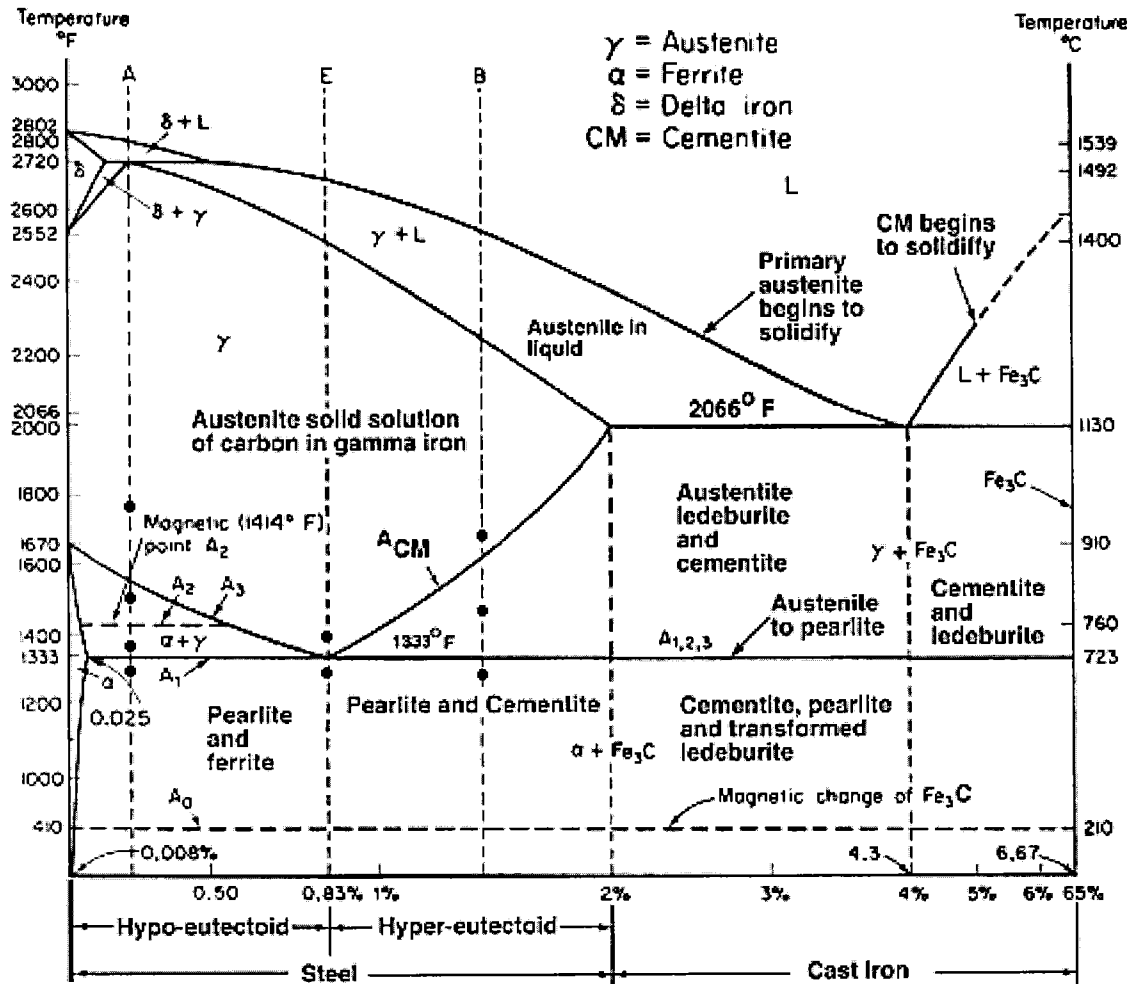
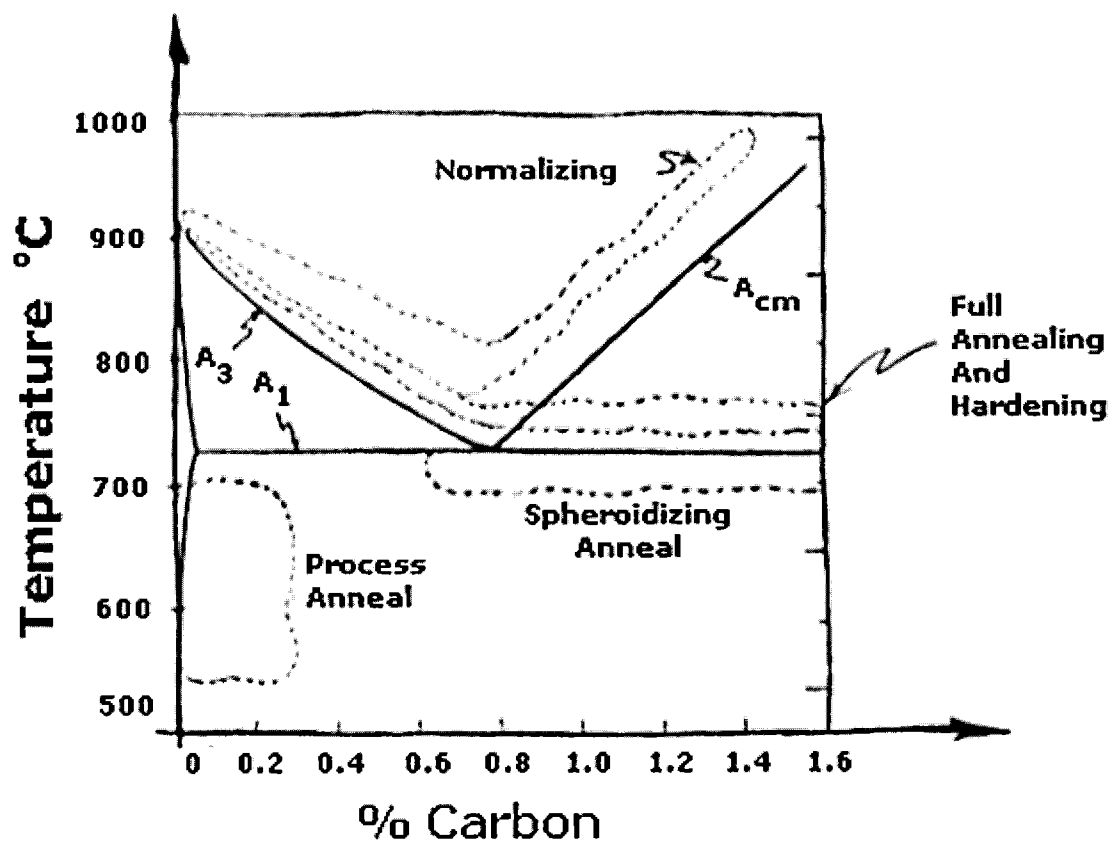


FIG. 1



HEAT TREATMENT PROCESS

FIG. 2

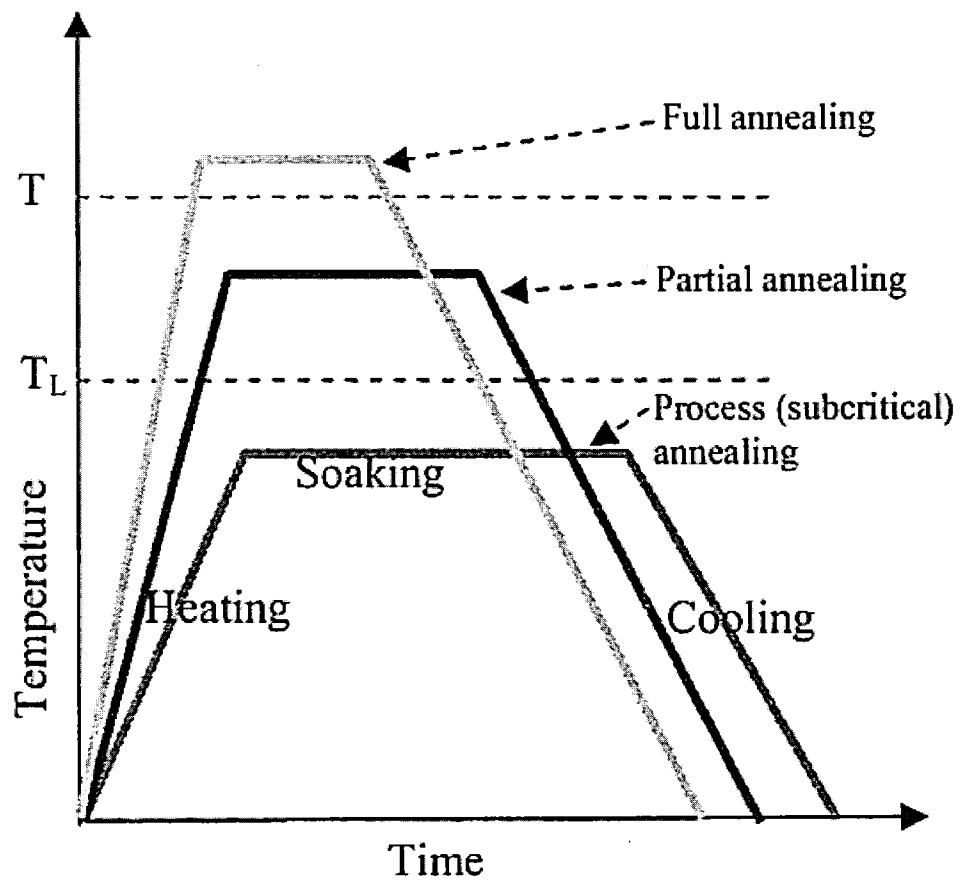


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/001541

A. CLASSIFICATION OF SUBJECT MATTER INV. C21D9/663 B21C47/26 C21D9/673 C21D9/675 C21D1/26 F27B11/00 F27D5/00 ADD. According to International Patent Classification (IPC) or to both national classification and IPC																	
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C21D B21C F27B F27D Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data																	
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td>US 3 181 846 A (ALFRED TEPLITZ) 4 May 1965 (1965-05-04) column 1, line 40 - column 2, line 59; claims 1-8; figures 1-5 -----</td> <td style="text-align: center; vertical-align: top;">1-41</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td>DE 27 22 632 A1 (BRITISH STEEL CORP) 1 December 1977 (1977-12-01) claims 1-11; figure 1 -----</td> <td style="text-align: center; vertical-align: top;">1-41</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>US 3 281 290 A (PLATE RAYMOND C) 25 October 1966 (1966-10-25) claim 1; figures 1-4 -----</td> <td style="text-align: center; vertical-align: top;">1-41</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>US 3 114 539 A (LEE WILSON ET AL) 17 December 1963 (1963-12-17) claims 1-4; figures 1-5 ----- -/-</td> <td style="text-align: center; vertical-align: top;">1-41</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	US 3 181 846 A (ALFRED TEPLITZ) 4 May 1965 (1965-05-04) column 1, line 40 - column 2, line 59; claims 1-8; figures 1-5 -----	1-41	X	DE 27 22 632 A1 (BRITISH STEEL CORP) 1 December 1977 (1977-12-01) claims 1-11; figure 1 -----	1-41	A	US 3 281 290 A (PLATE RAYMOND C) 25 October 1966 (1966-10-25) claim 1; figures 1-4 -----	1-41	A	US 3 114 539 A (LEE WILSON ET AL) 17 December 1963 (1963-12-17) claims 1-4; figures 1-5 ----- -/-	1-41
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A	US 3 281 290 A (PLATE RAYMOND C) 25 October 1966 (1966-10-25) claim 1; figures 1-4 -----	1-41															
A	US 3 114 539 A (LEE WILSON ET AL) 17 December 1963 (1963-12-17) claims 1-4; figures 1-5 ----- -/-	1-41															
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.																	
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family																	
Date of the actual completion of the international search 8 December 2015		Date of mailing of the international search report 17/12/2015															
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Catana, Cosmin															

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2015/001541

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 923 556 A (ISZCZUKIEWICZ LUDWIG C) 2 December 1975 (1975-12-02) claims 1-6; figures 1-6 -----	1-41
A	EP 0 314 876 A1 (NIPPON STEEL CORP [JP]) 10 May 1989 (1989-05-10) claims 1-6; figures 1-5 -----	1-41

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Information on patent family members

International application No

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