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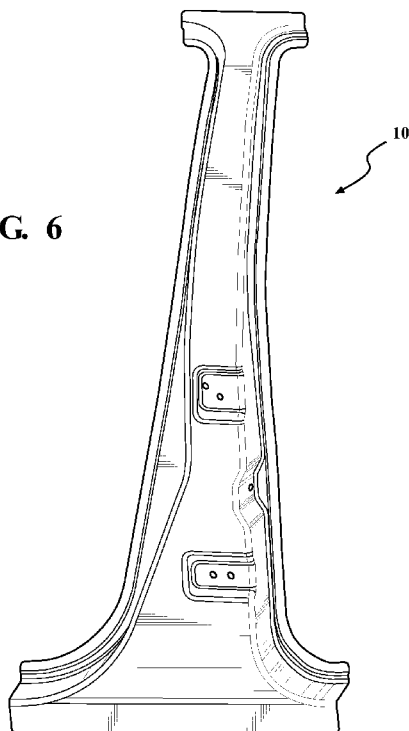
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(54) Title: AUSTEMPERING OF STRUCTURAL COMPONENTS

FIG. 6



(57) Abstract: An austempered structural steel component for an auto-
motive vehicle, and a method for manufacturing the component, is
provided. The structural component can be a twist axle, spring link,
control arm, pillar, trailer hitch, bumper, body or suspension attachment
bracket for a truck frame, or other chassis, body in white, or safety-re-
lated component. The structural component is at least partially formed
of medium carbon steel having a bainitic microstructure. The medium
carbon steel can include 0.2 to 1.0 wt. % carbon, 0.1 to 3.0 wt. % man-
ganese, not greater than 2.0 wt. % silicon, 0.0 to 0.010 wt. % boron, not
greater than 0.1 wt. % sulfur, and not greater than 0.2 wt. % phosphor-
ous. The medium carbon steel provides a yield strength of 900 to 1500
MPa. The structural component is also lighter and can potentially be
manufactured with reduced costs, compared to structural components
formed from other steel materials.



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AUSTEMPERING OF STRUCTURAL COMPONENTS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This PCT patent application claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 62/002,287 filed May 23, 2014 entitled “Austempering Of Structural Components”, the entire disclosure of the application is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The invention relates generally to structural steel components for automotive vehicles and trucks, and methods for manufacturing the structural steel components.

2. Related Art

[0003] Structural components for automotive vehicles and trucks, including light, medium, and heavy-duty trucks, are oftentimes formed from hot stamped steel, ultra high strength steel (UHSS), advanced high strength steel (AHSS), high strength steel (HSS), or cast iron. Although the hot stamped components provide high strength, use of the hot stamped components is limited due to low ductility and/or high manufacturing costs. The UHSS and AHSS materials are high cost and are oftentimes difficult to form into the complex shapes required for many automotive vehicle or truck applications. By comparison, the HSS materials are cost effective, easier to form, and can provide good ductility, but provide limited strength. However, additional forming and joining multiple components into a finished assembly will impart residual stresses that may be detrimental to the performance of the assembly. Components formed of cast iron also tend to be costly and heavy compared to formed steel.

SUMMARY OF THE INVENTION

[0004] The invention provides a method of manufacturing a structural steel component for an automotive vehicle or truck, for example a light, medium, or heavy-duty truck. The structural component has exceptional strength, reduced mass, and potentially reduced manufacturing costs, compared to structural components formed from ultra-high strength steel (UHSS), advanced high strength steel (AHSS), high strength steel (HSS), or cast iron. The structural steel component is formed from a medium carbon steel material and can be shaped to form a twist axle, spring link, control arm, pillar, trailer hitch, bumper, body or suspension attachment bracket for a truck frame, or other chassis component, body in white component, or safety-related component.

[0005] According to one embodiment, the method includes providing a shaped component formed at least partially from a medium carbon steel material; and austempering the shaped component. The austempering step includes transforming the microstructure of the medium carbon steel material to a microstructure consisting predominantly of bainite.

[0006] Another embodiment provides a method of manufacturing an austempered structural component for an automotive vehicle or truck formed at least partially from a medium carbon steel material having a microstructure which includes bainite. In this embodiment, the medium carbon steel material includes 0.2 to 1.0 wt. % carbon (C), 0.1 to 3.0 wt. % manganese (Mn), not greater than 2.0 wt. % silicon (Si), not greater than 0.010 wt. % boron (B), not greater than 0.1 wt. % sulfur (S), and not greater than 0.2 wt. % phosphorous (P), based on the total weight of the medium carbon steel material.

[0007] The invention also provides an austempered structural component for an automotive vehicle or truck comprising a medium carbon steel material having a microstructure consisting predominantly of bainite.

[0008] Another embodiment provides an austempered structural component for an automotive vehicle or truck comprising a medium carbon steel material and having a microstructure which includes bainite. In this embodiment, the medium carbon steel material includes 0.2 to 1.0 wt. % carbon (C), 0.1 to 3.0 wt. % manganese (Mn), not greater than 2.0 wt. % silicon (Si), not greater than 0.010 wt. % boron (B), not greater than 0.1 wt. % sulfur (S), and not greater than 0.2 wt. % phosphorous (P), based on the total weight of the medium carbon steel material. The medium carbon steel material is shaped to form a twist axle, spring link, control arm, pillar, trailer hitch, bumper, body or suspension attachment bracket for a truck frame, or other chassis component, body in white component, or safety-related component.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0010] Figure 1 illustrates a method of manufacturing an austempered structural component according to an example embodiment;

[0011] Figure 2 illustrates phases of an example austempering process;

[0012] Figure 3 is a Time Temperature Transformation (TTT) curve of the example austempering process;

[0013] Figure 4 illustrates an example upper bainite microstructure;

[0014] Figure 5 illustrates an example lower bainite microstructure;

[0015] Figure 5A is an enlarged view of a portion of the lower bainite structure shown in Figure 5;

[0016] Figure 6 is a perspective view of a B-pillar formed according to an example embodiment;

[0017] Figure 7 is a perspective view of a chassis spring link formed according to an example embodiment;

[0018] Figure 8 is a perspective view of a chassis front lower control arm formed according to an example embodiment;

[0019] Figure 9 is a perspective view of a trailer hitch formed according to an example embodiment;

[0020] Figure 10 is a perspective view of a twist axle assembly formed according to an example embodiment; and

[0021] Figure 11 is a perspective view of a suspension attachment bracket for a truck frame formed according to an example embodiment.

DESCRIPTION OF THE EXAMPLE EMBODIMENTS

[0022] A method of manufacturing an austempered structural steel component for an automotive vehicle or truck, for example a light, medium, or heavy-duty truck, according to one example embodiment, is generally shown in Figure 1. The structural component can be used as a twist axle, spring link, control arm, pillar, trailer hitch, bumper, body or suspension attachment bracket for a truck frame, or any other type of strength driven chassis component, body in white component, or safety-related component. The structural component includes medium carbon steel material formed to a predetermined shape and then austempered to achieve a bainitic microstructure. The structural component provides exceptional strength, for example a yield strength ranging from 900 MPa to 1500 MPa, with reduced mass, compared to structural components formed from ultra-high strength steel (UHSS), advanced high strength steel (AHSS), high strength steel (HSS), or cast iron. The structural component can also be manufactured with reduced manufacturing time and potentially lower manufacturing costs, compared to the structural components formed of other types of steel material. Additionally, the austempering process will temper the

material, relieving residual stress from the forming and joining operations, and potentially improve the durability performance of the structural component.

[0023] The structural component is manufactured by first providing at least one sheet, blank, or other workpiece formed at least partially of the medium carbon steel material. In one embodiment, the medium carbon steel material is provided in the form of a coil and then cut into a plurality of sheets, blanks, or workpieces. The medium carbon steel material is typically less costly to manufacture, and thus less expensive to purchase than ultra-high strength steel (UHSS), advanced high strength steel (AHSS), high strength steel (HSS), and cast iron.

[0024] In one example embodiment, the medium carbon steel material includes 0.2 to 1.0 weight percent (wt. %) carbon (C), 0.1 to 3.0 wt. % manganese (Mn), not greater than 2.0 wt. % silicon (Si), not greater than 0.010 wt. % boron (B), not greater than 0.1 wt. % sulfur (S), and not greater than 0.2 wt. % phosphorous (P), based on the total weight of the medium carbon steel material. In another example, the medium carbon steel material includes 0.25 to 0.45 weight percent (wt. %) carbon (C), 0.4 to 2.0 wt. % manganese (Mn), not greater than 1.0 wt. % silicon (Si), not greater than 0.010 wt. % boron (B), not greater than 0.05 wt. % sulfur (S), and not greater than 0.1 wt. % phosphorous (P), based on the total weight of the medium carbon steel material. The medium carbon steel material can also include other alloying elements and/or incidental impurities in addition to manganese (Mn), sulfur (S), and phosphorous (P). The balance of the composition typically consists of iron (Fe). For example, the medium carbon steel material can include iron (Fe) in an amount of at least 50 wt. %, or at least 70.0 wt. %, or at least 90.0 wt. %, based on the total weight of the medium carbon steel material. In another example embodiment, the medium carbon steel material is SAE 1038. The SAE 1038 material includes 0.35 to 0.41 wt. % carbon (C), 0.6 to 0.9 wt. % manganese (Mn), 0.07 to 0.6 wt. % silicon (Si), 0.0 to 0.010 wt.

% boron (B), not greater than 0.05 wt. % sulfur (S), not greater than 0.04 wt. %

phosphorous (P) or not greater than 0.03 wt. % phosphorous (P), and a balance of iron (Fe).

Table 1 below provides three example steel compositions that can be used as the medium carbon steel material.

Table 1

	Example 1	Example 2	Example 3
Carbon (C)	0.2 -> 1.0	0.25 -> 0.45	0.35 -> 0.41
Manganese (Mn)	0.1 -> 3.0	0.4 -> 2.0	0.6 -> 0.9
Silicon (Si)	< 2.0	< 1.0	0.07 -> 0.6
Boron (B)	< 0.01	< 0.01	< 0.01
Sulfur (S)	< 0.1	< 0.05	< 0.05
Phosphorous (P)	< 0.2	< 0.1	< 0.04

[0025] The medium carbon steel material used to form the structural component could also be referred to as a low to medium carbon steel material. The sheet, blank, or workpiece used to form the structural component should have an appropriate size and thickness, which depends on the type of structural component to be formed and its application.

[0026] The method can also include forming the structural component from a plurality of different steel materials, wherein at least one of the steel materials is the medium carbon steel material. The second steel material is different from the medium carbon steel material, for example a low carbon steel material, such as SAE 1010, or any UHSS, AHSS, or HSS material. The second steel material is not selected to form bainite during the austempering process, like the medium carbon steel material. The different steel materials are typically provided as separate sheets, blanks, or workpieces. In one example

embodiment, the method includes providing a first blank formed of the medium carbon steel material, specifically SAE 1038, and a second blank formed of the second steel material, specifically SAE 1010 which is a low carbon steel material. Alternatively, the different steel materials can be provided in a single sheet, blank, or workpiece. For example, the different steel materials can be mixed together, or the different steel materials can form distinct regions of the single sheet, blank, or workpiece.

[0027] The method next includes shaping the at least one sheet, blank, or workpiece to a predetermined shape. The predetermined shape is typically selected such that after the austempering process, the structural component can be used in an automotive vehicle or truck application, including light, medium, or heavy-duty truck application. The shaping step typically includes stamping, bending, and/or molding the at least one blank, sheet, or workpiece. However, the shaping step can also or alternatively include piercing, pinching, cutting, shearing, and/or any other type of metal forming operation. The strength of the medium carbon steel material is relatively low at this point during the manufacturing process, for example, the yield strength typically ranges from 300 to 500 MPa at this point. Thus, the shaping step can be conducted without heating the medium carbon steel material. In other words, the medium carbon steel material is easier to form than ultra high strength steel (UHSS), advanced high strength steel (AHSS), and potentially the high strength steel (HSS).

[0028] If two or more sheets, blanks, or workpieces are used to form the structural component, then the method can include forming the separate components independent of one another to achieve distinct shapes, and then joining the shaped components together. The joining step typically includes welding, but other types of joining techniques could be used, such as brazing, friction stir welding, or mechanical fastening. Alternatively, the two

or more sheets, blanks, or workpieces can be joined first and then formed together to achieve a predetermined shape.

[0029] After the shaping and possible joining steps, the method includes austempering the shaped component to increase the yield strength of the medium carbon steel material, for example to achieve a yield strength ranging from 900 to 1500 MPa. Figure 2 illustrates phases of the austempering process according to one example embodiment, and Figure 3 is a Time Temperature Transformation (TTT) curve of the austempering process according to the example embodiment. The TTT curve was obtained from The Hand Book on Mechanical Maintenance, available at <http://practicalmaintenance.net/?p=1345>. The process is typically conducted in an inert atmosphere to prevent scaling along the shaped component. When the shaped component includes two or more different steel materials, the different steel materials are subjected to the same austempering process, at the same time.

[0030] The austempering process first includes heating the shaped component until the medium carbon steel material includes austenite, and typically predominantly austenite. Preferably, the medium carbon steel material is heated until it reaches a fully austenitized state, wherein the microstructure of the steel material consists essentially of austenite. Typically, the heating step includes heating the shaped component to a temperature above 750° C, for example between 800° C and 950° C. The duration of the heating step **T1** can vary depending on the type and quantity of steel material used. If the shaped component includes two or more different steel materials, then the heating step is typically conducted until the microstructure of each steel material includes austenite or consists essentially of austenite. The heating step can be conducted in an oven.

[0031] Once the at least one steel material of the shaped component is austenitized, the austempering process includes rapidly quenching the shaped component to a

predetermine temperature, and maintaining the quenched component at that predetermined temperature until the microstructure of the medium carbon steel material includes bainite. Preferably, the microstructure of the medium carbon steel material consists predominantly of bainite or essentially of bainite by the end of the quenching step. In other words, the majority of the microstructure of the medium carbon steel material is bainite. The quenching step is conducted at a rate **T2** fast enough to prevent transformation of the austenite microstructure of the medium carbon steel material to another microstructure different from bainite. Preferably, the quenching step is conducted quickly enough to avoid the “nose” region of the TTT curve shown in Figure 3, where an undesired phase transformation would begin.

[0032] The predetermined temperature selected for the quenching step causes the microstructure of the medium carbon steel material to transform from austenite to bainite, and thus the temperature depends on the specific steel material employed. Typically, the predetermined temperature achieved at the end of the quenching step ranges from 300 to 600° C. In the example embodiment, the quenching step is a batch process conducted in a nitrite and/or nitrate salt bath. However, other quenching techniques can be used, including continuous processing during the part forming process. The amount of time **T3** that the shaped component is held at the predetermined temperature in the quenching process also varies depending on the type of steel material used.

[0033] The steps of quenching and maintaining the shaped component at the predetermined temperature during the quenching process can cause the austenite of the medium carbon steel material to transform to various different types of bainite microstructures, depending on the specific temperature and type of medium carbon steel material employed. In the example embodiment wherein the medium carbon steel material

is SAE 1038, either an upper bainite microstructure or a lower bainite microstructure is formed.

[0034] The upper bainite microstructure is also referred to as “feathery bainite.” It comprises very small cementite platelets generally oriented parallel with the long direction of the ferrite needles, and thus the upper bainite microstructure resembles pearlite. The upper bainite microstructure also typically provides a hardness around Rockwell C 40. However, the hardness will vary based on the material and the temperature. Figure 4 illustrates an example upper bainite microstructure.

[0035] The lower bainite microstructure is also referred to as “acicular bainite.” As the transformation temperature decreases, the ferrite needles become thinner and the carbide platelets become smaller and more closely spaced. The cementite platelets also reorient to an angle relative to the long axis of the ferrite needles. The lower bainite microstructure comprises a black needle-like structure and thus resembles martensite. The cementite platelets of the lower bainite microstructure are typically oriented at an angle of about 55 degrees relative to the long axis of the ferrite needles. The hardness of the lower bainite microstructure is typically around Rockwell C 60. However, the hardness will vary based on the material and the temperature. Figure 5 illustrates an example lower bainite microstructure. The photomicrographs used to draft Figures 4 and 5 were obtained from The Hand Book on Mechanical Maintenance, available at <http://practicalmaintenance.net/?p=1345>.

[0036] When the shaped component is formed of two or more different steel materials, each material is subjected to the same austempering process. In one embodiment, each of the different steel materials transforms from an austenitic to a bainitic microstructure. In another embodiment, while the medium carbon steel material transforms to the bainitic microstructure, the at least one other steel material present in the shaped

component transforms to a microstructure different from the bainitic microstructure. For example, during the phase transformation of the first blank formed of SAE 1038 joined to the second blank formed of SAE 1010, the SAE 1038 material transforms from an austenitic microstructure to a lower bainite microstructure while the SAE 1010 material transforms from an austenitic microstructure to a mixed microstructure consisting primarily of ferrite and pearlite, and including a lesser amount of bainite and martensite. In another embodiment, the shaped component includes the medium carbon steel material mixed with a second steel material different from the medium carbon steel material, and thus the finished structural component includes a mixture of different microstructures. The different steel materials present in the shaped component can achieve various other microstructures during the phase transformation step while the medium carbon steel material transforms to the bainitic microstructure.

[0037] After the microstructure transformation is complete, the structural component can be coated, painted, and/or shipped as normal. The steps of the method of manufacturing the structural component, including the phases of the austempering process, can all be performed at the same geographical location, or can be performed at various different geographical locations. For example, the sheets, blanks, or workpieces can be shaped and welded at one location, and then austempered at another location.

[0038] The structural component provided by the present invention includes the medium carbon steel material having the bainitic microstructure, such as an upper bainite or lower bainite microstructure. As discussed above, the structural component can include at least one second steel material in addition to and different from the medium carbon which has a microstructure different from the bainitic microstructure. For example, the structural component can include the first blank formed of the medium carbon steel material having the bainitic microstructure welded to the second blank formed of the SAE 1010 low carbon

steel material having the microstructure which consists consisting primarily of ferrite and pearlite, and including a lesser amount of bainite and martensite.

[0039] The structural component provided by the invention can be used in various different automotive or truck applications, including light, medium, and heavy-duty truck applications. For example, the structural component can be used as a twist axle, spring link, control arm, pillar, trailer hitch, bumper, body or suspension attachment bracket for a truck frame, or any other type of strength driven chassis component, body in white component, or safety-related component. The structural component also provides exceptional strength, for example a strength ranging from 900 MPa to 1500 MPa, reduced mass, and potentially reduced costs, compared to structural components formed from ultra-high strength steel (UHSS), advanced high strength steel (AHSS), high strength steel (HSS), and cast iron. Figures 6-11 illustrate several example structural components **10** each formed at least partially of the austempered medium carbon steel material with the bainitic microstructure.

[0040] The structural component **10** of Figure 6 is a B-pillar formed entirely of the austempered medium carbon steel material with the bainitic microstructure.

[0041] The structural component **10** of Figure 7 is a chassis spring link including first parts **12** formed of the austempered low to medium carbon steel material with the bainitic microstructure and second parts **14** formed of the low carbon steel material with the mixed microstructure. The first parts **12** of the spring link are beams and the second parts **14** are bushings.

[0042] The structural component **10** of Figure 8 is a chassis front lower control arm including first parts **12** formed of the austempered low to medium carbon steel material with the bainitic microstructure and second parts **14** formed of the low carbon steel material with the mixed microstructure. The first parts **12** of the control arm are wishbone-shaped plates and the second parts **14** are bushings.

[0043] The structural component **10** of Figure 9 is a trailer hitch including a plurality of parts **12** each formed of the austempered low to medium carbon steel material with the bainitic microstructure. The parts **12** of the trailer hitch include a tubular arm, mounting brackets, and a receiver tube.

[0044] The structural component **10** of Figure 10 is a twist axle assembly including first parts **12** formed of the austempered low to medium carbon steel material with the bainitic microstructure and second parts **14** formed of the low carbon steel material with the mixed microstructure. The first parts **12** of the twist axle assembly include an elongated beam, control arms, spindle brackets, and spring brackets. The second parts **14** of the twist axle assembly include conventional connectors and bushings.

[0045] The structural component **10** of Figure 11 is a suspension attachment bracket for a truck frame, such as a light, medium, or heavy-duty truck frame. The suspension bracket includes a plurality of parts **12** each formed of the austempered medium carbon steel material with the bainitic microstructure. The parts **12** of the suspension attachment bracket are joined together, for example by welding.

[0046] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the following claims.

CLAIMS

In The Claims:

Claim 1. A method of manufacturing a structural component for an automotive vehicle or truck, comprising the steps of:

providing a shaped component formed at least partially from a medium carbon steel material; and

austempering the shaped component, wherein the austempering step includes transforming the microstructure of the medium carbon steel material to a microstructure consisting predominantly of bainite.

Claim 2. The method of Claim 1, wherein the medium carbon steel material includes 0.2 to 1.0 wt. % carbon (C), 0.1 to 3.0 wt. % manganese (Mn), not greater than 2.0 wt. % silicon (Si), not greater than 0.010 wt. % boron, not greater than 0.1 wt. % sulfur (S), and not greater than 0.2 wt. % phosphorous (P), based on the total weight of the medium carbon steel material.

Claim 3. The method of Claim 2, wherein the medium carbon steel material includes 0.25 to 0.45 wt. % carbon (C), 0.4 to 2.0 wt. % manganese (Mn), not greater than 1.0 wt. % silicon (Si), not greater than 0.01 wt. % boron (B), not greater than 0.05 wt. % sulfur (S), and not greater than 0.1 wt. % phosphorous (P), based on the total weight of the medium carbon steel material.

Claim 4. The method of Claim 1, wherein the austempering step includes heating the shaped component until the microstructure of the medium carbon steel material includes austenite, and quenching the heated shaped component until the microstructure of

the medium carbon steel material transforms to the microstructure consisting predominantly of bainite.

Claim 5. The method of Claim 4, wherein the heating step includes heating the medium carbon steel material to a temperature above 750° C, and the quenching step includes cooling the medium carbon steel material to a temperature of 300 to 600° C.

Claim 6. The method of Claim 1, wherein the shaped component is partially formed of at least one second steel material different from the medium carbon steel material.

Claim 7. The method of Claim 6, wherein the step of providing the shaped component includes mixing the medium carbon steel material and the at least one second steel material to provide a single workpiece, and shaping the single workpiece.

Claim 8. The method of Claim 6, wherein the step of providing the shaped component includes providing a first workpiece formed of the medium carbon steel material, providing a second workpiece formed of the at least one second steel material, and joining the workpieces together.

Claim 9. The method of Claim 6, wherein the austempering step includes heating the medium carbon steel material and the at least one second steel material together until the microstructure of both steel materials includes austenite, and quenching the medium carbon steel material and the at least one second steel material together until the medium carbon steel material has a microstructure consisting predominantly of bainite and

the at least one second steel material has a microstructure different from the microstructure consisting predominantly of bainite.

Claim 10. The method of Claim 1, wherein the step of providing the shaped component includes providing a workpiece formed at least partially from the medium carbon steel material, and shaping the workpiece to the shape of a twist axle, spring link, control arm, pillar, trailer hitch, bumper, body or suspension attachment bracket, or other chassis, body in white, or safety-related component.

Claim 11. The method of Claim 1, wherein the step of providing the shaped component includes providing a workpiece formed at least partially from the medium carbon steel material and shaping the workpiece to the shape of a twist axle, spring link, control arm, pillar, trailer hitch, bumper, body or suspension attachment bracket, or other chassis, body in white, or safety-related component;

the medium carbon steel material includes 0.25 to 0.45 wt. % carbon (C), 0.4 to 2.0 wt. % manganese (Mn), not greater than 1.0 wt. % silicon (Si), not greater than 0.01 wt. % boron (B), not greater than 0.05 wt. % sulfur (S), and not greater than 0.1 wt. % phosphorous (P), based on the total weight of the medium carbon steel material;

the austempering step includes heating the shaped component to a temperature above 750° C in an oven until the microstructure of the medium carbon steel material consists essentially of austenite;

the austempering step further includes quenching the heated shaped component to a temperature of 300 to 600° C in a nitrite and/or nitrate salt bath, and holding the quenched shaped component at a temperature of 300 to 600° C until the microstructure of the medium

carbon steel material transforms from the microstructure consisting essentially of austenite to the microstructure consisting predominantly of bainite; and

the microstructure consisting predominantly of bainite includes at least one of upper bainite and lower bainite.

Claim 12. A method of manufacturing a structural component for an automotive vehicle or truck, comprising the steps of:

providing a shaped component formed at least partially from a medium carbon steel material, the medium carbon steel material including 0.2 to 1.0 wt. % carbon (C), 0.1 to 3.0 wt. % manganese (Mn), not greater than 2.0 wt. % silicon (Si), not greater than 0.010 wt. % boron (B), not greater than 0.1 wt. % sulfur (S), and not greater than 0.2 wt. % phosphorous (P), based on the total weight of the medium carbon steel material; and

austempering the shaped component, wherein the austempering step includes transforming the microstructure of the medium carbon steel material to a microstructure including bainite.

Claim 13. The method of Claim 12, wherein the medium carbon steel material includes 0.25 to 0.45 wt. % carbon (C), 0.4 to 2.0 wt. % manganese (Mn), not greater than 1.0 wt. % silicon (Si), not greater than 0.01 wt. % boron (B), not greater than 0.05 wt. % sulfur (S), and not greater than 0.1 wt. % phosphorous (P), based on the total weight of the medium carbon steel material.

Claim 14. A structural component for an automotive vehicle or truck, comprising:

a medium carbon steel material, the medium carbon steel material being austempered and having a microstructure consisting predominantly of bainite.

Claim 15. The structural component of Claim 14, wherein the medium carbon steel material includes 0.2 to 1.0 wt. % carbon (C), 0.1 to 3.0 wt. % manganese (Mn), not greater than 2.0 wt. % silicon (Si), 0.0 to 0.010 wt. % boron (B), not greater than 0.1 wt. % sulfur (S), and not greater than 0.2 wt. % phosphorous (P), based on the total weight of the medium carbon steel material.

Claim 16. The structural component of Claim 15, wherein the medium carbon steel material includes 0.25 to 0.45 wt. % carbon (C), 0.4 to 2.0 wt. % manganese (Mn), not greater than 1.0 wt. % silicon (Si), 0.0 to 0.010 wt. % boron (B), not greater than 0.05 wt. % sulfur (S), and not greater than 0.1 wt. % phosphorous (P), based on the total weight of the medium carbon steel material.

Claim 17. The structural component of Claim 14, wherein the medium carbon steel material is shaped to form a twist axle, spring link, control arm, pillar, trailer hitch, bumper, body or suspension attachment bracket, or other chassis, body in white, or safety-related component.

Claim 18. The structural component of Claim 14 further including at least one second steel material different from the medium carbon steel material.

Claim 19. The structural component of Claim 18, wherein the at least one second steel material is mixed with the medium carbon steel material.

Claim 20. The structural component of Claim 18, wherein the at least one second steel material is joined to the medium carbon steel material.

Claim 21. The structural component of Claim 18, wherein the at least one second steel material has a microstructure different from the microstructure of the medium carbon steel material consisting predominantly of bainite.

Claim 22. A structural component for an automotive vehicle or truck, comprising:

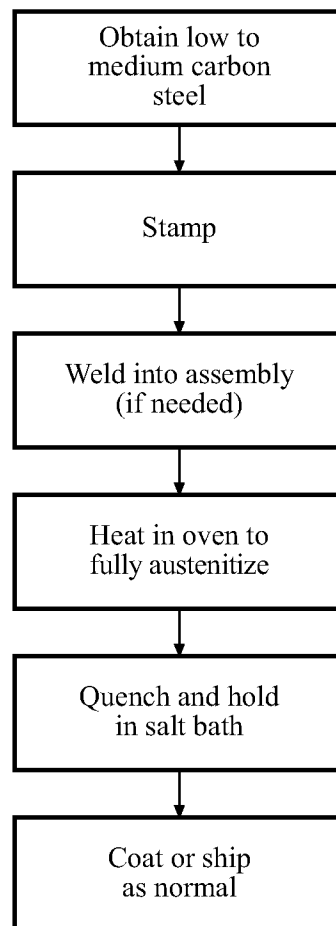
a medium carbon steel material including 0.2 to 1.0 wt. % carbon (C), 0.1 to 3.0 wt. % manganese (Mn), not greater than 2.0 wt. % silicon (Si), 0.0 to 0.010 wt. % boron (B), not greater than 0.1 wt. % sulfur (S), and not greater than 0.2 wt. % phosphorous (P), based on the total weight of the medium carbon steel material; and

the medium carbon steel material being austempered and having a microstructure including bainite.

Claim 23. The structural component of Claim 22, wherein the medium carbon steel material includes 0.25 to 0.45 wt. % carbon (C), 0.4 to 2.0 wt. % manganese (Mn), not greater than 1.0 wt. % silicon (Si), 0.0 to 0.010 wt. % boron (B), not greater than 0.05 wt. % sulfur (S), and not greater than 0.1 wt. % phosphorous (P), based on the total weight of the medium carbon steel material.

Claim 24. The structural component of Claim 22, wherein the medium carbon steel material is shaped to form a twist axle, spring link, control arm, pillar, trailer hitch, bumper, body or suspension attachment bracket, or other chassis, body in white, or safety-related component.

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**FIG. 1**

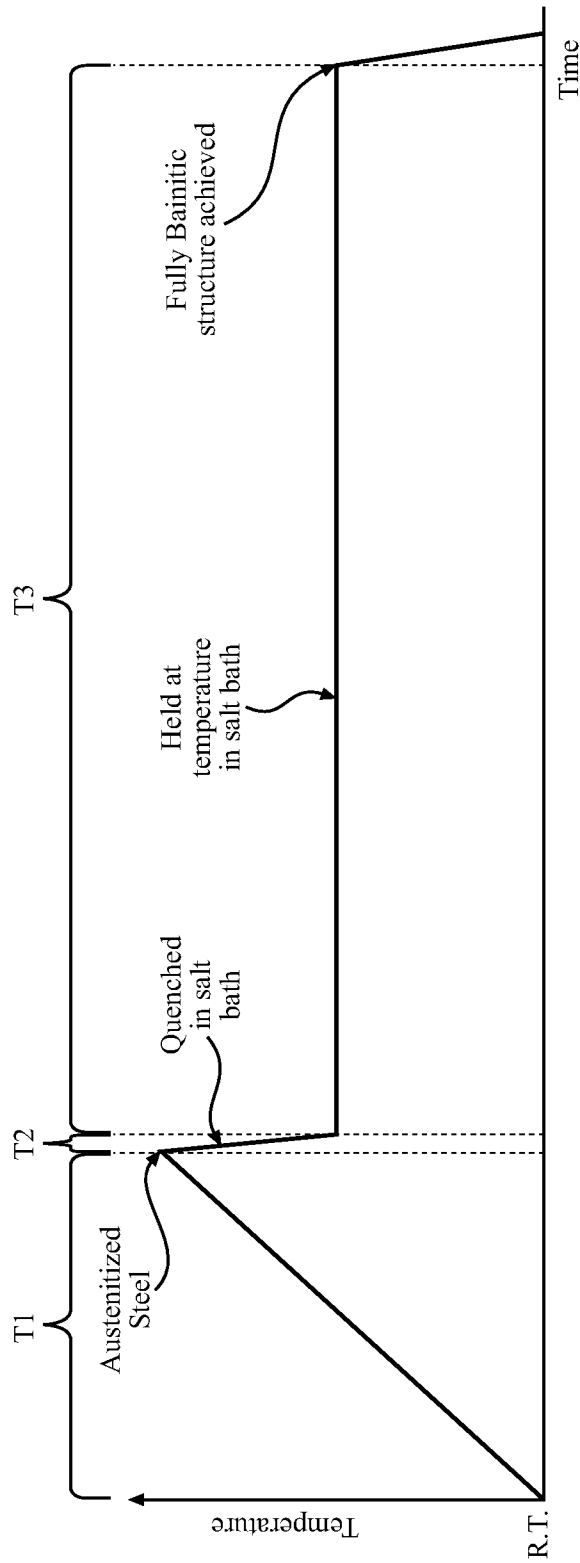
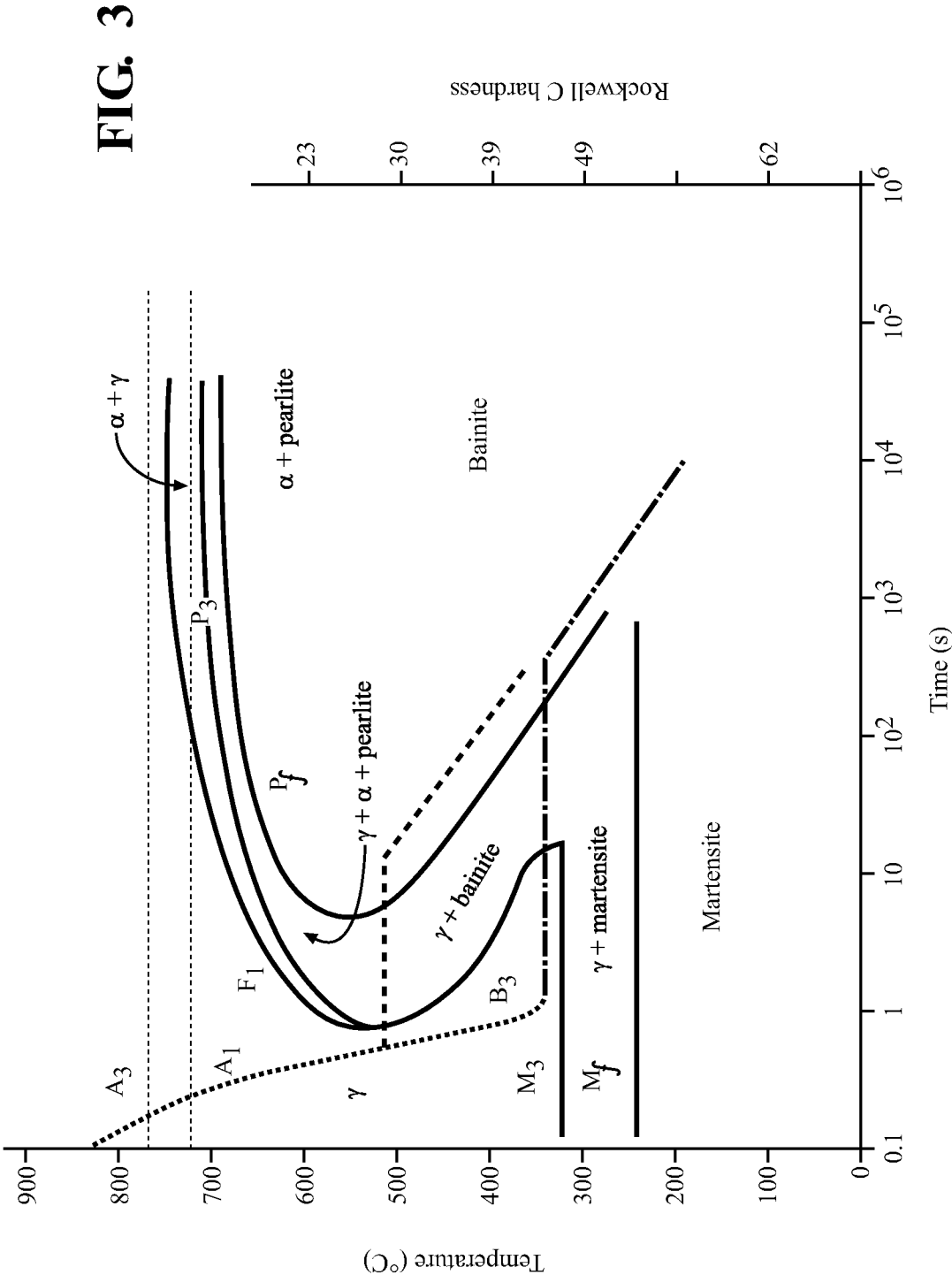


FIG. 2



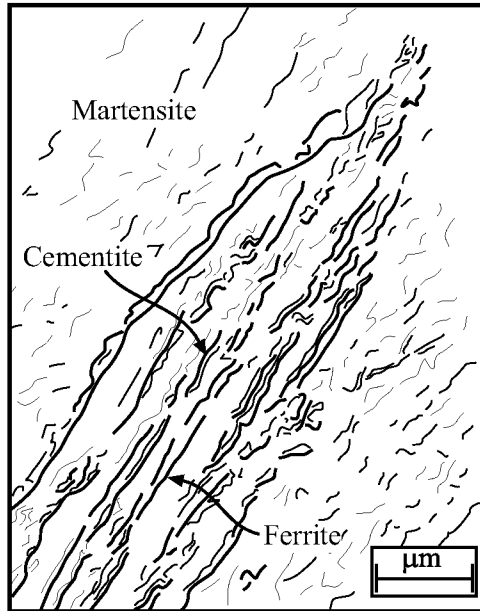


FIG. 4



FIG. 5

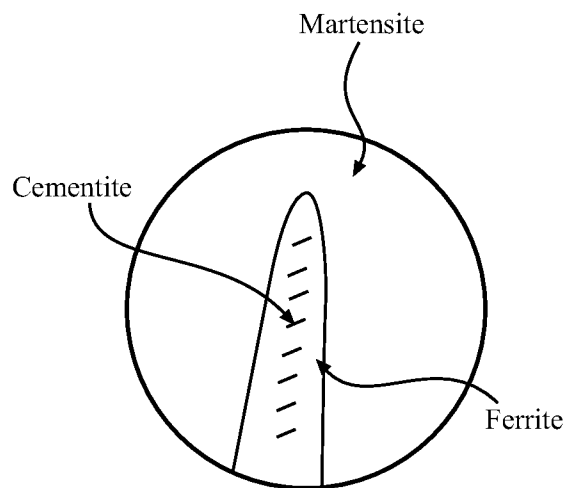
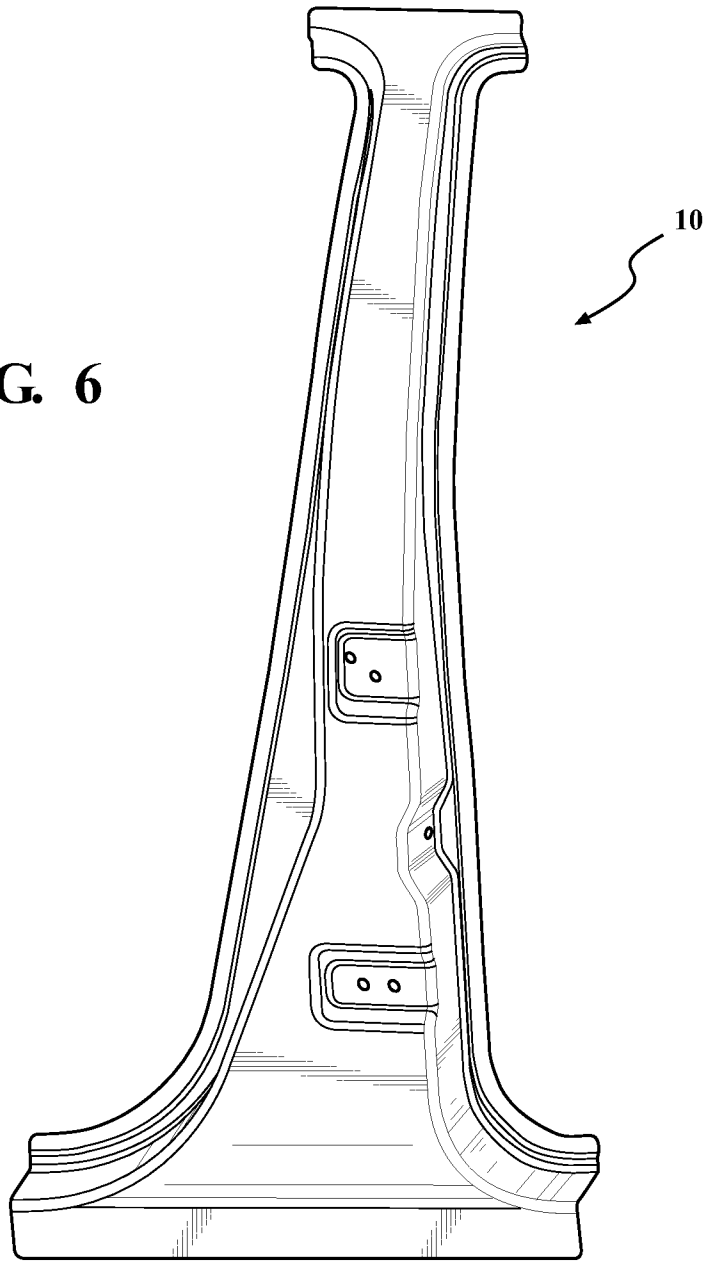


FIG. 5A

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FIG. 6



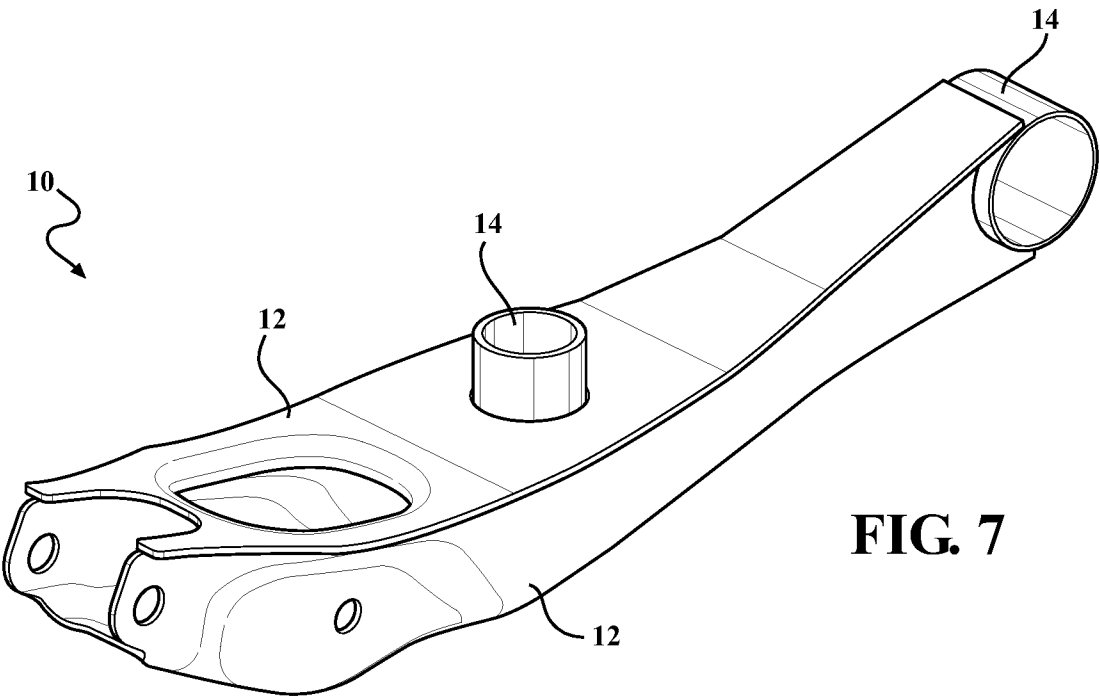


FIG. 7

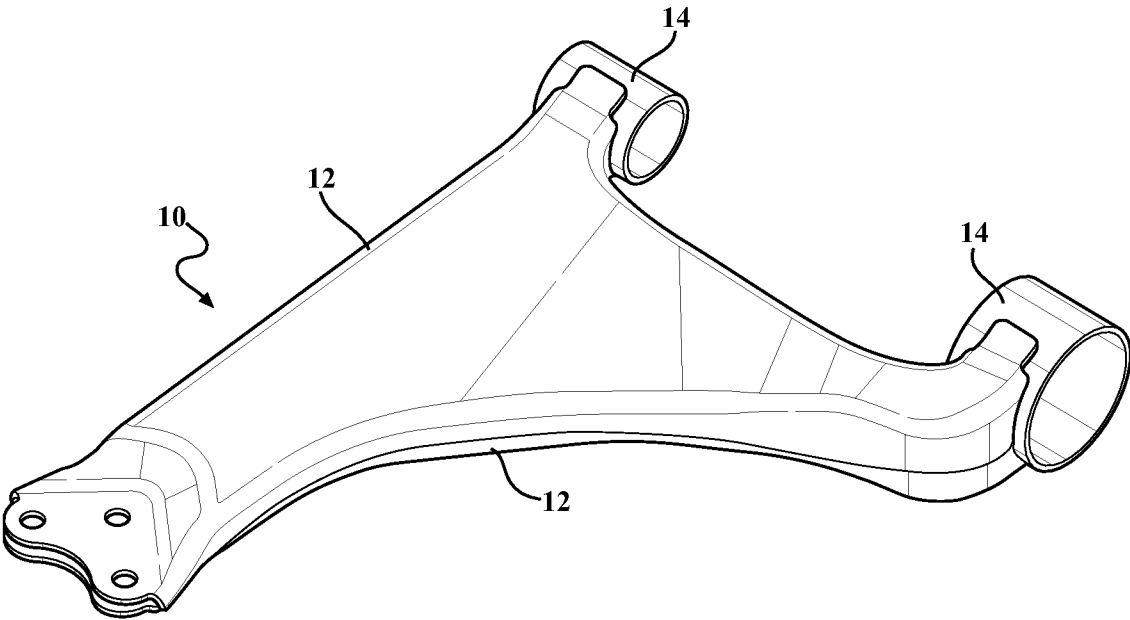


FIG. 8

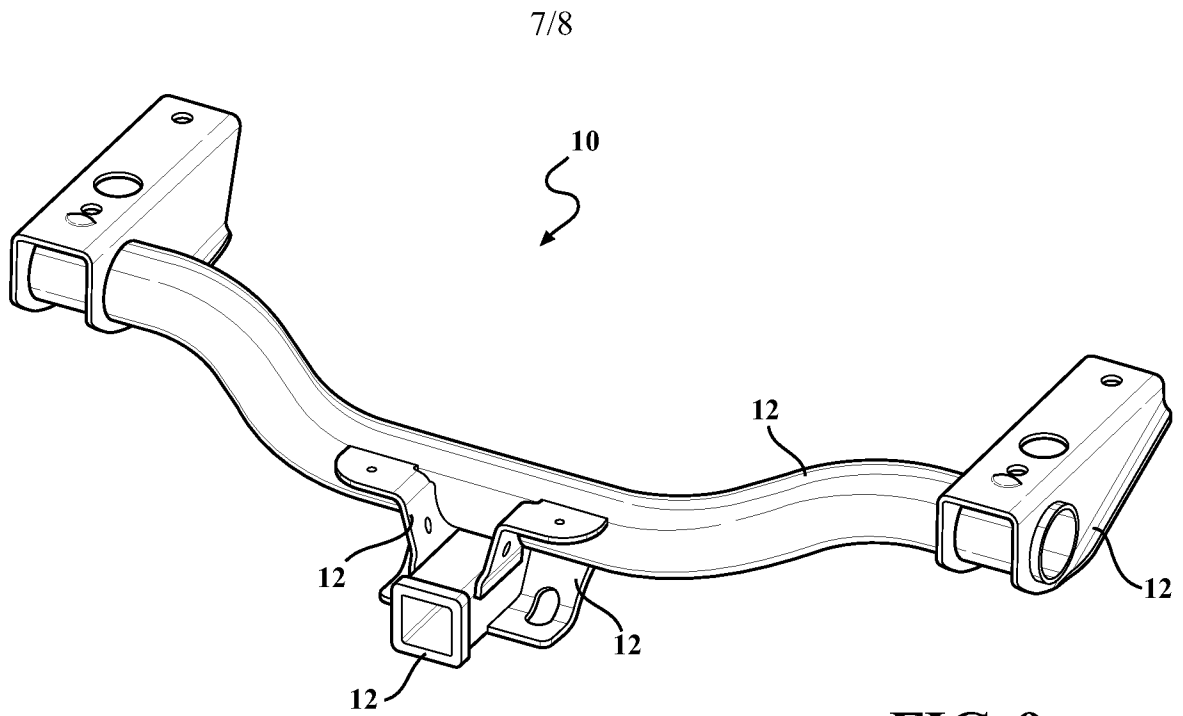


FIG. 9

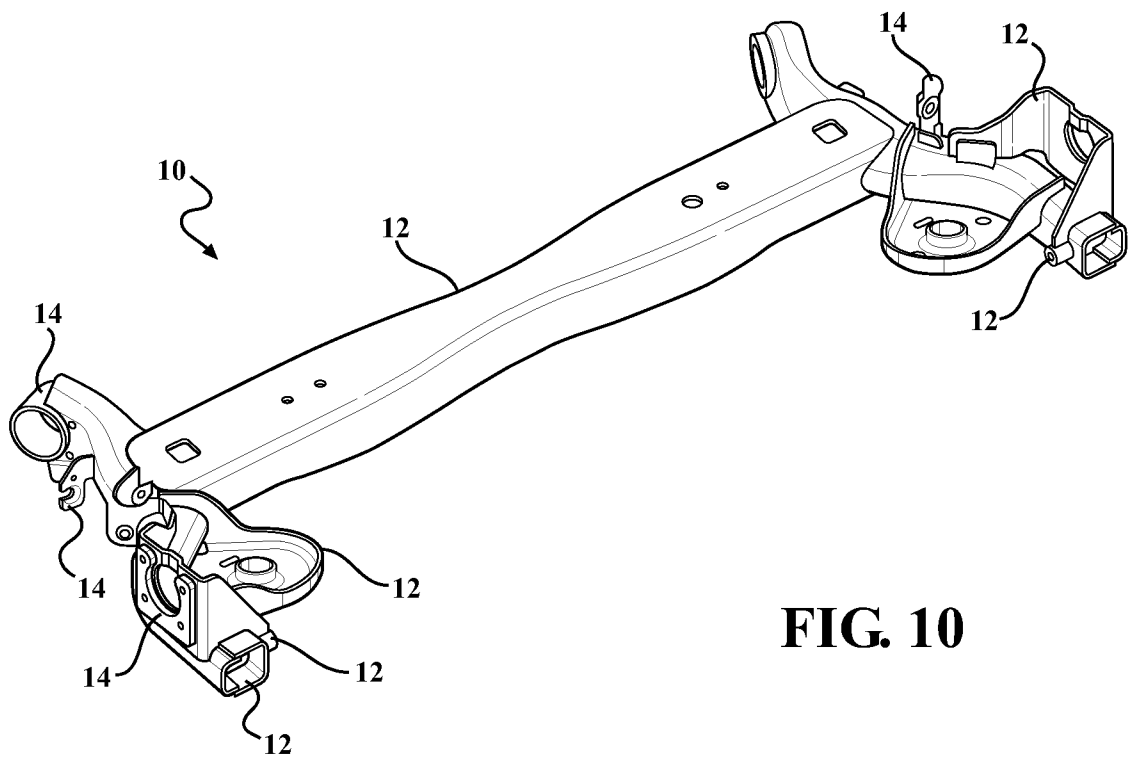
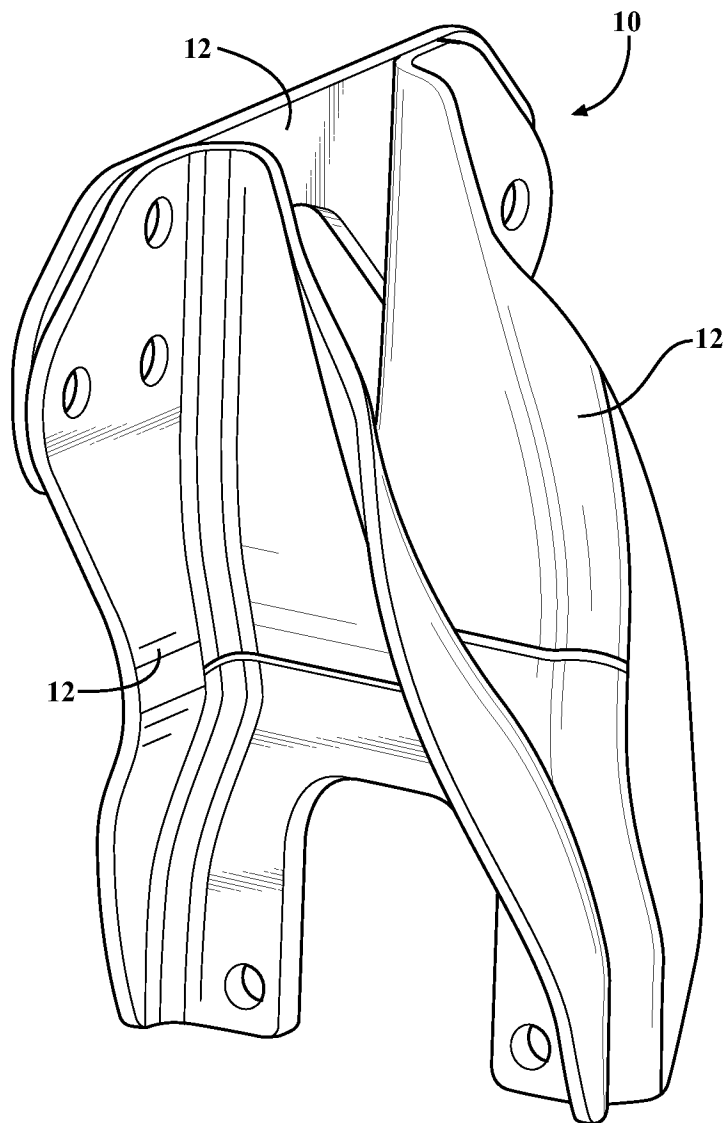


FIG. 10

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 15/32158

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - C21D 6/00 (2015.01)

CPC - C21D 1/18; C21D 2211/008; C21D 1/19

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)

CPC (C21D1/18; C21D2211/008; C21D1/19; C22C38/04; C22C38/12; C22C38/06; C21D1/20; C21D9/30; C21D2211/002; C22C38/001; C21D7/13; C22C38/02; Y10T428/12458; B23K26/3206; B23K26/34; B23K35/004; C22C1/002; B23K20/00; B23K26/03; B22F2998/00; B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 USPC (148/663; 148/637; 148/662; 428/610; 219/121.73; 228/101; 427/405; 228/196; 148/218; 148/620; 148/603; 148/619; 148/575; 148/590; 148/566; 266/128; 148/653; 266/121; 266/130; 148/595; 148/660; 148/661; 148/334; 148/654; 148/532; 148/632; 29/888.6; 428/

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 PatBase, Google Patents/Scholar - Terms: Carbon medium steel iron bainite austenite austempering vehicle 0.25-0.45 manganese join shape mix different parts structural heat quench another nitrate nitrite salt bath stainless Mn car truck automotive trailer hitch bumper suspension axle form mold die weld fuse connect pieces material blend melt thermal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/146812 A1 (MEDINA et al.) 1 November 2012 (01.11.2012) [machine translated]	1-5, 10, 12-17 and 22-24
—	translated: pg 4, para 7-8; pg 5; pg 6; pg 7, para 1; pg 8, para 3; pg 13, para 2-5; claims 1 and 4-7; table 5; abstract	6-8, 11 and 18-21
Y	original: pg 6, ln 26-30; pg 7, ln 25-32; pg 8; pg 9; pg 10; pg 11, ln 2; pg 12, ln 30-36; pg 20, ln 12-30	9
—		
A		
Y	US 2009/0208773 A1 (DUPONT) 20 August 2009 (20.08.2009)	6-8 and 18-21
—	Para [0003], [0007], [0028]; claims 2 and 3	9
A		
Y	WO 2013/188100 A1 (COLA) 19 December 2013 (19.12.2013)	7 and 19
—	pg 4, ln 4-24; pg 6, ln 28-30; pg 7, ln 1; pg 9, ln 7-10; abstract	
Y	US 2,194,872 A (SAIVES) 26 March 1940 (26.03.1940)	11
—	pg 1, col 2; ln 22-27; pg 2, col 2, ln 22-26	
A	US 6,177,205 B1 (KAIS et al.) 23 January 2001 (23.01.2001)	9
—	col 1, ln 54-67; abstract; claim 7	
A	US 2009/0302094 A1 (MILAM) 10 December 2009 (10.12.2009)	9
—	para [0022]-[0025], [0027]; abstract	

☐ Further documents are listed in the continuation of Box C.


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"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

17 July 2015 (17.07.2015)

Date of mailing of the international search report

05 AUG 2015

Name and mailing address of the ISA/US

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