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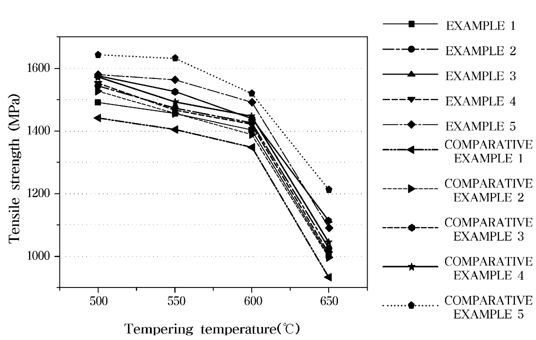
(54) **HIGH-STRENGTH WIRE ROD FOR COLD HEADING, HAVING EXCELLENT HEAT TREATMENT CHARACTERISTICS AND HYDROGEN DELAYED FRACTURE CHARACTERISTICS, HEAT TREATMENT COMPONENT, AND MANUFACTURING METHODS THEREFOR**

(57) Disclosed in the present specification are: a high-strength wire rod for cold heading, having superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, the rod being applicable to a bolt, etc.; a heat-treated component; and a method for manufacturing the same. According to an exemplary embodiment, the high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics comprises, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N, and Fe and other impurities as the balance, and has a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, and comprises $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

【FIG. 1】



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Description

[Technical Field]

[0001] The present disclosure relates to a high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, a heat-treated component, and a method for manufacturing the same. More particularly, it relates to a high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, which is applicable to a high-strength bolt, etc., a heat-treated component, and a method for manufacturing the same.

[Background Art]

[0002] In general, wire rods for cold heading are classified into process-eliminated wire rods for cold heading with heat treatment and machining processes eliminated and high-strength wire rods for cold heading that allow weight reduction of components.

[0003] The high-strength wire rod for cold heading is manufactured by cold-heating a wire rod after spheroidization heat treatment, and then it is prepared into a heat-treated component such as a mechanical structure, an automobile part, etc. through quenching and tempering.

[0004] However, the metal structure of a general wire rod is mainly composed of pearlite, and there is an inconvenience in that heat treatment for a long time is required to dissolve cementite during austenitization heat treatment.

[0005] In addition, a tempered martensite microstructure is formed when austenitization heat treatment is performed. It is difficult to use the tempered martensite microstructure because it is very sensitive to resistance of hydrogen-delayed fracture at 1300 MPa or higher.

[0006] Accordingly, it is necessary to develop a high-strength wire rod for cold heading with superior resistance of hydrogen-delayed fracture characteristics at 1300 MPa or higher.

[Disclosure]

[Technical Problem]

[0007] The present disclosure is directed to providing a high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, a heat-treated component, and a method for manufacturing the same.

[Technical Solution]

[0008] The present disclosure provides a high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, which comprises, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N, and Fe and other impurities as the balance, and has a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, and comprises $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

[0009] The high-strength wire rod may have a prior austenite average grain size of 10 μm or smaller.

[0010] The martensite may be comprised of 60% or higher in the prior austenite grain boundary.

[0011] The present disclosure also provides a method for manufacturing a high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, which comprises: heating a billet comprising, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N and Fe and other impurities as the balance at 1000-1200 °C, conducting hot rolling at a finish hot rolling temperature of 750-950 °C, and conducting cooling at a cooling rate of 0.2-1.0 °C/s, wherein the cooled wire rod has a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, and comprises $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

[0012] The present disclosure also provides a heat-treated component with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, which comprises, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N and Fe and other impurities as the balance, and has a microstructure comprising, by area fraction, 90% or more of tempered martensite, and comprises $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

[0013] The heat-treated component may have a prior austenite average grain size of 5 μm or smaller.

[0014] In addition, the heat-treated component with superior resistance of hydrogen-delayed fracture characteristics may have a tensile strength of 1400 MPa or higher and an impact toughness of 60 J or higher.

[0015] The present disclosure also provides a method for manufacturing a heat-treated component with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, which comprises: preparing a wire rod comprising, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N and Fe and other impurities as the balance and having a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, wherein the martensite is comprised of 60% or higher in the prior austenite grain into a steel wire by conducting spheroidization heat treatment and drawing once or more times, preparing the prepared steel wire into a component by conducting cold heading, heating the prepared component at 800-900 °C for 1,000-2,000 seconds, quenching the heated component at 50-150 °C, and tempering the quenched component at 500-600 °C for 3,000-10,000 seconds.

[Advantageous Effects]

[0016] According to an exemplary embodiment of the present disclosure, since the microstructure comprises, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, austenitization heat treatment can be conducted quickly and, thus, the energy consumed for heat treatment can be reduced.
[0017] According to an exemplary embodiment of the present disclosure, since the wire rod has a microstructure and fine carbide is distributed therein, resistance of hydrogen-delayed fracture resistance can be improved.

[Brief Description of Drawings]

[0018]

FIG. 1 shows the tensile strength of examples and comparative examples.
FIG. 2 shows the impact toughness of examples and comparative examples.

[Best Mode]

[0019] The present specification discloses a high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, which comprises, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N and Fe and other impurities as the balance, and has a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite and comprises $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

[Mode for Invention]

[0020] Hereinafter, specific exemplary embodiments of the present disclosure are described. However, the exemplary embodiments of the present disclosure may be modified in various forms and the technical idea of the present disclosure is not limited to the embodiments described below. In addition, the exemplary embodiments of the present disclosure are provided to more completely explain the present disclosure to those having ordinary knowledge in the art.
[0021] The terms used in this application are used only to describe specific examples. Therefore, for example, singular expressions include plural expressions unless the context clearly indicates otherwise. In addition, the terms such as "include", "have", etc. used in this application are used to clearly indicate that the features, steps, functions, components or combinations thereof described in the specification exist, but do not preclude the presence of other features, steps, functions, components or combinations thereof.
[0022] Meanwhile, unless defined otherwise, all the terms used in the present specification should be regarded as having the same meanings commonly understood by those having ordinary knowledge in the technical field to which the present disclosure belongs. Therefore, unless explicitly defined in the present specification, certain terms should not be interpreted in an overly idealistic or formal sense. For example, in the present specification, singular expressions include plural expressions unless the context clearly indicates otherwise.
[0023] In addition, the expressions such as "about", "substantially", etc. in the present specification are used to indicate specific or similar numerical values within given tolerances. They are used to help understanding the present disclosure or prevent undue exploitation of the disclosure by unscrupulous infringers.
[0024] A high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics according to the present disclosure comprises, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N and Fe and other impurities as the balance.
[0025] The reason why the alloy composition is limited will be described in detail. The composition means wt% unless specified otherwise.

Carbon (C): 0.3-0.6 wt%

[0026] C is an element added to ensure the strength of a product. If the content of C is less than 0.3%, it is difficult to ensure the target strength, and it is not easy to ensure sufficient hardenability after final Q/T (quenching/tempering) heat treatment. On the contrary, if the content of C exceeds 0.6%, fatigue life is reduced due to excessive generation of carbide. Accordingly, in the present disclosure, the upper limit of the C content is limited to 0.6%.

Silicon (Si): 0.05-0.3 wt%

[0027] Si an element that is used not only for deoxidization of steel but also for ensuring strength through solid solution strengthening. In the present disclosure, Si is added in an amount of 0.05% or more for ensuring deoxidization and strength. But, if the content is excessive, it is difficult to process complex parts such as a bolt because of unsatisfactory cold heading property. Accordingly, in the present disclosure, the upper limit of the Si content is limited to 0.3%.

Manganese (Mn): 0.2-1.0 wt%

[0028] Mn is an element which is advantageous in ensuring strength by improving the hardenability of parts, increases rollability and reduces brittleness. It is added in an amount of 0.2% or more in order to ensure sufficient strength. But, if the content is excessive, a hard tissue may be formed easily during cooling after hot rolling and fatigue property may be deteriorated due to the generation a large amount of MnS inclusions. Accordingly, in the present disclosure, the upper limit of the Mn content is limited to 1.0%.

Chromium (Cr): 0.5-2.0 wt%

[0029] Cr is an element which is effective for improving hardenability together with Mn and improves the corrosion resistance. If the Cr content is less than 0.5%, enough corrosion resistance cannot be ensured. On the other hand, if the content is excessive, there are problems that impact toughness is decreased and coarse carbide with poor resistance of hydrogen-delayed fracture resistance is formed. Accordingly, in the present disclosure, the upper limit of the Cr content is limited to 2.0%.

Molybdenum (Mo): 0.5-2.0 wt%

[0030] Mo is an element which improves hardenability through precipitation hardening by precipitation of fine carbide and solid solution hardening. The improvement of hardenability by Mo is more effective as compared to Mn or Cr. If the Mo content is less than 0.5%, it is not easy to ensure strength because fine carbide is not precipitated sufficiently during Q/T heat treatment. On the other hand, if the content is excessive, the shape of the part is distorted after quenching due to excessively high hardenability, requiring an additional process for correction or resulting in microcrack defects in the parts. Accordingly, in the present disclosure, the upper limit of the Mo content is limited to 2.0%.

Aluminum (Al): 0.02-0.05 w%

[0031] Al is an element widely used as a deoxidizing agent in steelmaking processes. Al reacts with N to form aluminum nitride (AlN) and refines austenite grains. If the Al content is less than 0.02%, grain refinement is not easy because the amount of the nitrogen compound is insufficient. On the other hand, if the content is excessive, the occurrence of defects may be intensified due to excessive formation of non-metallic inclusions such as alumina. Accordingly, in the present disclosure, the upper limit of the Al content is limited to 0.05%.

Nitrogen (N): 0.01-0.03 w%

[0032] N is an element used for grain refinement instead of the expensive alloying element. N reacts with Al to form aluminum nitride (AlN) and refines austenite grains. If the content of N is less than 0.01%, grain refinement is not easy because the amount of the nitrogen compound is insufficient. On the other hand, if the content is excessive, dislocation and deposition occur during cold heading due to heading heat, resulting in decreased mold life due to fixation of free nitrogen and increased deformation strength. Accordingly, in the present disclosure, the upper limit of the N content is limited to 0.03%.

[0033] The remaining component is iron (Fe). But, the mixing of unwanted impurities from the raw materials or the surrounding environment cannot be excluded. The impurities will not be described in detail because they are known to those skilled in the art.

[0034] In addition, because coarse carbonitride strongly traps hydrogen and can cause hydrogen embrittlement, it is necessary to prevent its formation as much as possible. For reference, vanadium (V), which is frequently added to high-strength CHQ (cold heading quality) steel with a tensile strength of 1400 MPa or higher, can form coarse carbide having poor resistance of hydrogen-delayed fracture resistance. In the present disclosure, V is not added so that no undissolved coarse carbide remains after Q/T heat treatment even when a large part with a body diameter of 16-30 mm is manufactured. Through this, resistance of hydrogen-delayed fracture resistance can be ensured.

[0035] The wire rod for cold heading according to an exemplary embodiment of the present disclosure has a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite. When the wire rod has such a microstructure, the heat treatment time for dissolving cementite during austenitization heat treatment can be reduced.

[0036] In addition, the microstructure may contain $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm and may have a prior austenite average grain size of 10 μm or smaller. When $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm is comprised, austenite grains can be refined and resistance of hydrogen-delayed fracture resistance can be improved. Here, the prior austenite grain boundary of the wire rod refers to the grain boundary of the austenite structure of the wire rod after winding and before cooling.

[0037] In addition, 60% or more of martensite may be comprised in the prior austenite grain boundary. When 60% or more of martensite is comprised in the prior austenite grain boundary, a tensile strength of 1400 MPa or higher and an impact toughness of 60 J or higher can be ensured.

[0038] The inventors of the present disclosure have found out that the strength and resistance of hydrogen-delayed fracture resistance of the wire rod for cold heading can be improved further when the contents of C, Cr and Mo satisfy a specific condition, and have derived the following relation. In an exemplary embodiment of the present disclosure, the wire rod for cold heading may satisfy the following formula (1) while satisfying the above-described alloy composition.

$$(1)\ 7.2\ C + Cr + 2.7\ Mo \geq 6.65$$

[0039] In the formula (1), C, Cr and Mo mean the wt% of each element. If there is an element other than C, Cr and Mo, 0 is allocated for the element.

[0040] In order to further improve resistance of hydrogen-delayed fracture resistance, fine carbide that can trap diffusible hydrogen is necessary. The fine carbides that can trap hydrogen comprise CrC and MoC carbides having Cr and Mo as main components, respectively. Only when a certain number of the fine carbides is ensured, a strength of 1400 MPa or higher can be ensured at the tempering temperature of 500-600 °C and the effect of hydrogen trapping can be maximized. Considering this, by controlling the alloy composition to satisfy the formula (1), the strength and resistance of hydrogen-delayed fracture resistance of the heat-treated component at the high tempering temperature (500-600 °C) can be improved.

[0041] Hereinafter, a method for manufacturing a high-strength wire rod for cold heading with superior resistance of hydrogen-delayed fracture characteristics according to the present disclosure will be described.

[0042] The method for manufacturing a high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics according to an exemplary embodiment of the present disclosure may comprise a step of heating a billet satisfying the composition described above, a step of preparing the heated billet into a wire rod, and a step of cooling the wire rod.

[0043] In the step of heating the billet, the billet may satisfy the composition described above and may be heated at 1000-1200 °C. In addition, the billet may satisfy the formula (1).

[0044] In the step of preparing the heated billet into a wire rod, the heated billet may be prepared into a wire rod by finish hot-rolling at 750-950 °C and then winding.

[0045] In the step of cooling the wire rod, the wire rod may be cooled at a cooling rate of 0.2-1.0 °C/s such that the average austenite grain size after winding is 10 μm or smaller. The cooling may be performed by air cooling, although not being specially limited thereto.

[0046] The cooled wire rod may have a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, and the aerial ratio of the martensite formed in the prior austenite grain boundary may be 60% or higher. Here, the prior austenite grain boundary refers to the grain boundary of the austenite structure of the wire rod after winding and before cooling. In addition, the microstructure of the cooled wire rod may contain $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

[0047] Hereinafter, a method for manufacturing a high-strength heat-treated component with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics using the wire rod for cold heading described above will be described.

[0048] The method for manufacturing a high-strength heat-treated component with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics according to an exemplary embodiment of the present disclosure may comprise a step of lowering strength by spheroidization heat-treating the cooled wire rod, a step of preparing the wire rod into a component through cold heading, a step of heating the component, a step of quenching the heated component, and a step of tempering the quenched component. After the spheroidization heat treatment, drawing may be performed at least once. Hereinafter, each step will be described in detail.

[0049] The cooled wire rod may be prepared into a steel wire by conducting spheroidization heat treatment and drawing at least once. The spheroidization heat treatment is performed appropriately to process the steel before drawing, and the drawing may be performed appropriately in consideration of the drawing limit. According to the present disclosure, the wire rod may be prepared into a steel wire that can be prepared into a component of a complicated shape through spheroidization heat treatment and drawing.

[0050] The steel wire may be prepared into a component through cold heading. The component may be, for example, a screw, a bolt, etc. The bolt may have a body diameter of 12-30 mm.

[0051] Then, the component may be heated at high temperature. In the step of heating the component, the carbide precipitated during the rolling of the wire rod is redissolved. The component may be heated such that the alloy component has a uniform composition and has an average austenite grain size of 5 μm or smaller. In an exemplary embodiment, the component may be heated at 800-900 °C for 1000-2000 seconds.

[0052] In the step of quenching the heated component, the heated component may be quenched to 50-150 °C. The quenching may be performed by immersing the heated component in an oil at 50-150 °C, although not being specially limited thereto.

[0053] In the step of tempering the quenched component, the final microstructure of the heat-treated component is controlled to tempered martensite. In an exemplary embodiment, the tempering step may be performed by tempering at 500-600 °C. The tempering may be performed for 3000-10000 seconds.

[0054] The heat-treated component with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics prepared by the method described above may contain, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N and Fe and other impurities as the balance, and the microstructure may contain, by area fraction, 90% or more of tempered martensite and may contain $2 \times 10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

[0055] In addition, the prior austenite average grain size may be 5 μm or smaller. Here, the prior austenite grain boundary refers to the grain boundary of the austenite structure of the wire rod after winding and before cooling.

[0056] In addition, the tensile strength may be 1400 MPa or higher, and the impact toughness may be 60 J or higher. When the heat-treated component is a bolt, the final component with a body diameter of 12-30 mm may have a tensile strength of 1400 MPa or higher and an impact toughness of 60 J or higher.

[0057] In an exemplary embodiment of the present disclosure, the heat-treated component satisfying the alloy composition described above may satisfy the following formula (1). The restriction in the formula (1) will not be described here because it was described earlier.

$$(1)\ 7.2\ C + Cr + 2.7\ Mo \geq 6.65$$

[0058] In the formula (1), C, Cr and Mo mean the wt% of each element.

[0059] Hereinafter, the present disclosure will be described more specifically through examples. However, the following examples are only for illustrating the present disclosure more specifically and the technical idea of the present disclosure is not limited by the examples.

{Examples}

[0060] A billet having the composition described in Table 1 was heated to 1000-1200 °C, finish-rolled at 750-950 °C, and then wound at 730-900 °C. After the winding, the wire rod was cooled at a cooling rate of 0.2-1 °C/s. After the cooling was completed, the wire rod had a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, and the ratio of martensite formed in the prior austenite grain boundary was 60% or higher. In addition, it comprised $2 \times 10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

[0061] In Table 1, 'formula (1)' was calculated by substituting the contents (wt%) of C, Cr and Mo in the '7.2 C + Cr + 2.7 Mo' of the formula (1). The AlN number indicates the number of aluminum nitride with a size of 5-50 nm.

[Table 1]

Division	Alloy composition (wt%)							Formula (1)	Grain boundary martensite ratio (%)	AlN number (/m^3)
	C	Si	Mn	Cr	Mo	Al	N			
Example 1	0.32	0.11	0.71	1.23	1.19	0.04	0.015	6.747	63	4.3x10^{19}
Example 2	0.41	0.11	0.62	1.01	1.12	0.03	0.016	6.986	62	3.4x10^{19}
Example 3	0.56	0.12	0.82	0.81	0.92	0.03	0.016	7.326	64	3.6x10^{19}
Example 4	0.42	0.10	0.72	1.52	0.95	0.03	0.017	7.109	63	5.0x10^{19}
Example 5	0.40	0.11	0.56	0.57	1.45	0.03	0.014	7.365	70	3.1x10^{19}
Comparative Example 1	0.32	0.13	0.69	1.25	0.85	0.03	0.016	5.849	65	3.6x10^{19}
Comparative Example 2	0.40	0.11	0.65	0.94	1.19	0.04	0.015	7.033	54	3.7x10^{19}
Comparative Example 3	0.54	0.11	0.75	0.83	0.94	0.03	0.009	7.256	68	1.9x10^{19}
Comparative Example 4	0.43	0.13	0.66	2.12	1.05	0.03	0.016	8.051	72	3.4x10^{19}
Comparative Example 5	0.41	0.10	0.76	0.77	2.21	0.04	0.015	9.689	74	3.7x10^{19}

[0062] For the examples, the values of the formula (1) were 6.65 or higher, the grain boundary martensite ratio was 60% or higher, and the number of aluminum nitride with a size of 5-50 nm was 2×10^{19}/m^3 or more.

[0063] In contrast, for the comparative examples, the values of the formula (1) were lower than 6.65, the grain boundary martensite ratio was lower than 60%, the number of aluminum nitride with a size of 5-50 nm was smaller than 2×10^{19}/m^3, or the alloy composition was outside the range of 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al and 0.01-0.03% of N.

[0064] The hot-rolled wire rod having the composition described in Table 1 was processed into a cylindrical sample with a diameter of 25 mm, heated at 860 °C for 1,500 seconds, quenched by immersing in an oil at 100 °C, and then tempering at 500-600 °C for 5,000 seconds. Then, after processing into a test sample according to ASTM E8 and ASTM E23, tensile test and impact test were performed. The result of tensile test and impact test is shown in FIG. 1 and FIG. 2. All the examples exhibited a tensile strength of 1,400 MPa or higher and an impact toughness of 60 J or higher at the tempering temperature of 500-600 °C, whereas the comparative examples showed poor tensile strength and impact toughness.

[0065] Although the exemplary embodiments of the present disclosure have been described above, the present disclosure is not limited thereto and those having ordinary knowledge in the art will understand that various changes and modifications can be made without departing from the concept and scope of the appended claims.

[Industrial Applicability]

[0066] The present disclosure may provide a high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, a heat-treated component, and a method for manufacturing the same.

Claims

1. A high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, which comprises, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N, and Fe and other impurities as the balance, and has a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, and comprises 2×10^{19}/m^3 or more of aluminum nitride having a diameter of 5-50 nm.

2. The high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics according to claim 1, which has a prior austenite average grain size of 10 μm or smaller.

3. The high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics according to claim 1, wherein the martensite is comprised of 60% or higher in the prior austenite grain boundary.

4. A method for manufacturing a high-strength wire rod for cold heading with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, comprising:

heating a billet comprising, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N and Fe and other impurities as the balance at 1000-1200 °C,
hot rolling at a finish hot rolling temperature of 750-950 °C, and
cooling at a cooling rate of 0.2-1.0 °C/s,
wherein the cooled wire rod has a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, and comprises $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

5. A heat-treated component with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, which comprises, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N and Fe and other impurities as the balance, and has a microstructure comprising, by area fraction, 90% or more of tempered martensite, and comprises $2\times10^{19}/m^3$ or more of aluminum nitride having a diameter of 5-50 nm.

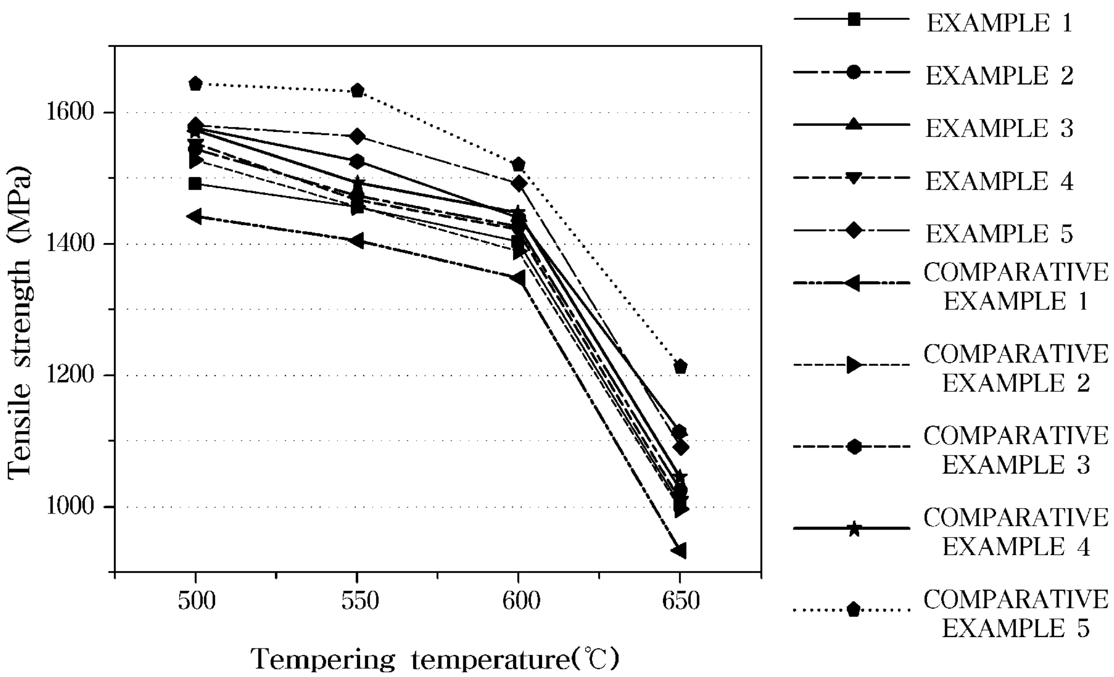
6. The heat-treated component with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics according to claim 5, which has a prior austenite average grain size of 5 μm or smaller.

7. The heat-treated component with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics according to claim 5, which has a tensile strength of 1400 MPa or higher and an impact toughness of 60 J or higher.

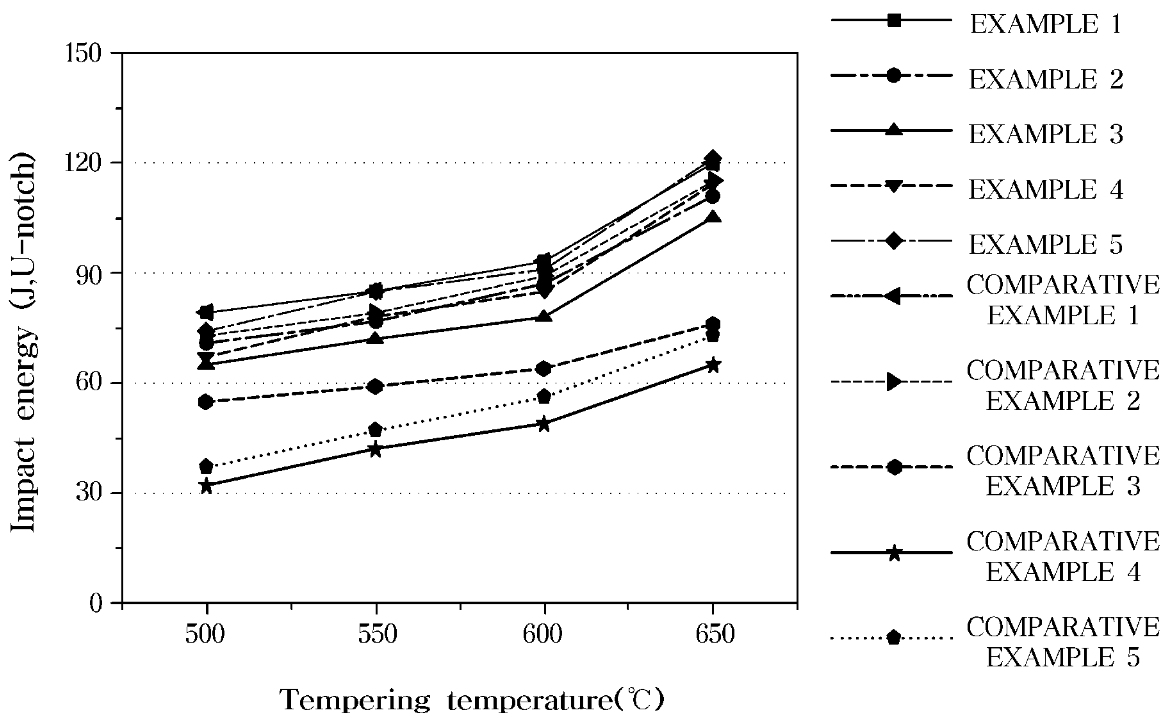
8. A method for manufacturing a heat-treated component with superior heat treatment characteristics and resistance of hydrogen-delayed fracture characteristics, comprising:

preparing a wire rod comprising, by wt%, 0.3-0.6% of C, 0.05-0.3% of Si, 0.2-1.0% of Mn, 0.5-2.0% of Cr, 0.5-2.0% of Mo, 0.02-0.05% of Al, 0.01-0.03% of N and Fe and other impurities as the balance and having a microstructure comprising, by area fraction, 80% or more of bainite, 1-15% of pearlite and 0.1-2% of martensite, wherein the martensite is comprised of 60% or higher in the prior austenite grain boundary into a steel wire by conducting spheroidization heat treatment and drawing once or more times,
preparing the prepared steel wire into a component by conducting cold heading,
heating the prepared component at 800-900 °C for 1,000-2,000 seconds,
quenching the heated component at 50-150 °C, and
tempering the quenched component at 500-600 °C for 3,000-10,000 seconds.

【FIG. 1】


EXAMPLE 1
EXAMPLE 2
EXAMPLE 3
EXAMPLE 4
EXAMPLE 5
COMPARATIVE EXAMPLE 1
COMPARATIVE EXAMPLE 2
COMPARATIVE EXAMPLE 3
COMPARATIVE EXAMPLE 4
COMPARATIVE EXAMPLE 5
1600
1400
1200
1000
Tensile strength (MPa)
500
550
600
650
Tempering temperature(℃)

【FIG. 2】


150
120
90
60
30
0
Impact energy (J,U-notch)
500
550
600
650
Tempering temperature(℃)
EXAMPLE 1
EXAMPLE 2
EXAMPLE 3
EXAMPLE 4
EXAMPLE 5
COMPARATIVE EXAMPLE 1
COMPARATIVE EXAMPLE 2
COMPARATIVE EXAMPLE 3
COMPARATIVE EXAMPLE 4
COMPARATIVE EXAMPLE 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2021/016963

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/22(2006.01)i; **C21D 9/52**(2006.01)i; **C21D 8/06**(2006.01)i

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)

C22C 38/22(2006.01); B23P 15/00(2006.01); C21D 8/06(2006.01); C21D 9/00(2006.01); C22C 38/00(2006.01); C22C 38/02(2006.01); C22C 38/06(2006.01); C22C 38/38(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS (KIPO internal) & keywords: 선재(bar wire), 베이나이트(bainite), 마르텐사이트(martensite), 펄라이트(pearlite), 냉간단조(cold forging), 몰리브덴(Molybdenum)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	KR 10-2019-0075378 A (POSCO) 01 July 2019 (2019-07-01) See claims 1-2, 4-5 and 8.	5-7 1-4,8
Y	KR 10-2019-0074824 A (POSCO) 28 June 2019 (2019-06-28) See paragraph [0037] and claims 1 and 4.	5-7
A	JP 2001-062639 A (KOBE STEEL LTD.) 13 March 2001 (2001-03-13) See paragraph [0043] and claims 1-2 and 5.	1-8
A	JP 2001-240940 A (NIPPON STEEL CORP.) 04 September 2001 (2001-09-04) See paragraph [0055] and claims 1-2.	1-8
A	KR 10-2018-0011427 A (POSCO) 01 February 2018 (2018-02-01) See paragraph [0072] and claims 1, 3 and 5.	1-8

☐ 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
"D" document cited by the applicant in the international application
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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	Date of mailing of the international search report
24 February 2022	**25 February 2022**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2021/016963

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		KR 10-1867677 B1	15 June 2018

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