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(54) WIRE ROD FOR ULTRAHIGH-STRENGTH SPRINGS, STEEL WIRE, AND MANUFACTURING METHOD THEREFOR

(57) Disclosed in the present specification are: a wire rod for ultrahigh-strength springs, which can be applied to motorcycle suspension springs; a steel wire; and a manufacturing method therefor. According to one embodiment of the disclosed wire rod for ultrahigh-strength springs, the wire rod comprises, by wt%, 0.5-0.7% of C, 0.4-0.9% of Si, 0.3-0.8% of Mn, 0.2-0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the balance of Fe and inevitable impurities, wherein in 1 mm2 area of the center of the cross-section perpendicular to the longitudinal direction, the proportion of the area satisfying at least one from among C>0.8%, Si>0.9%, Cr>0.8% and Mn>0.8% by wt% can be 5% or less.

EP 4 265 774 A1

Description

[Technical Field]

[0001] The disclosure relates to a wire rod and steel wire for ultrahigh strength springs, and method for manufacturing the same. More particularly, the disclosure relates to a wire rod and steel wire for ultrahigh strength springs, and method for manufacturing the same, which may be applied to motorcycle suspension springs.

[Background Art]

[0002] Similar to the car material market, the motorbike market is also constantly undergoing weight reduction or structural modification. Demand for high-strength spring steel is growing these days as dual-type suspensions having been used for existing motorbikes are being replaced with mono types.

[0003] The existing spring steel having been used for motorbike suspension is the hard steel wire that lacks enough strength and fatigue resistance to be used for the mono-type suspension. Hence, the steel having a tempered martensite (TM) structure for automobiles has been considered to be used, but it is hardly applied to the motorbike suspension spring because the automobile suspension spring has a strict management standard, gives difficulty in manufacturing and is expensive.

[0004] To solve this problem, there is a way of reducing the alloy content and lowering tempering temperature. With the reduced alloy content and the lowered tempering temperature, however, it is difficult to secure ductility at high strength, thereby leading to a problem of insufficient machinability. To solve this problem, segregation control for securing sufficient ductility even at low tempering temperature is required.

[0005] Furthermore, with the recent development of induction heat treatment (IT heat treatment) technology, sufficient hardenability may be secured even with the use of water cooling, and desired strength may be obtained while the content of an alloy element included in the steel is lowered. However, spring steel manufactured through IT heat treatment has a very severe material deviation depending on the degree of segregation. Especially, the material deviation due to the segregation tends to be more severe the higher the strength of the steel. Hence, control of segregation is required for securing high strength and stable reduction ratio of cross-section is required when the IT heat treatment is applied.

[0006] (Patent literature 1) Korean Patent Publication No. 1995-0018545 (published on July 22, 1995)

[Disclosure]

[Technical Problem]

[0007] To solve the aforementioned problems, the disclosure provides a high-quality wire rod and steel wire for ultrahigh strength spring, and method for manufacturing the same, capable of securing high strength and high reduction ratio of cross-section with small material deviation after induction heat treatment.

[Technical Solution]

[0008] According to an embodiment of the disclosure, a wire rod for ultrahigh strength spring includes in percent by weight (wt%), 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder having Fe and unavoidable impurities, wherein a ratio of an area satisfying one or more of C > 0.8%, Si > 0.9%, Cr > 0.8% and Mn > 0.8%, in wt%, in an area of 1 mm^2 of a center of a cross-section perpendicular to a longitudinal direction is 5% or less.

[0009] The wire rod for ultrahigh strength spring may include a surface ferrite decarburized layer having a thickness of 1 μm or less.

[0010] According to an embodiment of the disclosure, a method of manufacturing a wire rod for ultra-high strength spring includes preparing a bloom by continuous casting of molten steel including, in wt%, 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder having Fe and unavoidable impurities; and rolling the bloom into billets and then into wire rods, wherein the continuous casting is performed at a casting speed of 0.48 to 0.54 m/min and comprises soft reduction with a total amount of reduction of 15 to 35 mm during the continuous casting.

[0011] The soft reduction may be performed so that each roll rolls to 4 mm or less and a cumulative amount of reduction is 60% or more when the solidification fraction is 0.6 or more.

[0012] According to an embodiment of the disclosure, a steel wire for ultra-high strength spring, the steel wire comprising: in percent by weight (wt%), 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder having

Fe and unavoidable impurities, and for area fraction, 90% or more of tempered martensite, wherein a ratio of an area satisfying one or more of C > 0.8%, Si > 0.9%, Cr > 0.8% and Mn > 0.8%, in wt%, in an area of 1 mm^2 of a center of a cross-section perpendicular to a longitudinal direction is 5% or less.

[0013] The steel wire for ultrahigh strength spring may have hardness variation of 25 Hv or less in the cross-section perpendicular to the longitudinal direction except for an area having a depth of 0.5 mm or less from the top surface.

[0014] The steel wire for ultrahigh strength spring may have a tensile strength of 1750 to 2200 MPa and a cross-section reduction rate of 40% or more.

[0015] According to an embodiment of the disclosure, a method of manufacturing a steel wire for ultrahigh strength spring includes drawing the wire rod including, in wt%, 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder being Fe and unavoidable impurities, and having a ratio of an area satisfying one or more of C > 0.8%, Si > 0.9%, Cr > 0.8% and Mn > 0.8%, in wt%, in an area of 1 mm^2 of a center of a cross-section perpendicular to a longitudinal direction being 5% or less, into a wire; heating the wire at 900 to 1000°C within 10 seconds; water cooling the wire at high pressure; heating and tempering the wire at 400 to 500°C within 10 seconds; and water cooling the wire.

[Advantageous Effects]

[0016] The disclosure may provide a wire rod and steel wire for ultrahigh strength spring, and method for manufacturing the same, which may secure high strength even with a lower alloy content than in the traditional spring steel wire and secure an excellent cross-section reduction ratio with reduced center segregation, and may thus be applicable to products requiring a low spring index as well.

[0017] The disclosure may provide a high-quality wire rod and steel wire for ultrahigh strength spring, and method for manufacturing the same, capable of securing high strength and high cross-section reduction ratio with small material deviation after induction (IT) heat treatment.

[Best Mode]

[0018] According to an embodiment of the disclosure, a wire rod for ultra-high strength spring includes in percent by weight (wt%), 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder having Fe and unavoidable impurities, wherein a ratio of an area satisfying one or more of C > 0.8%, Si > 0.9%, Cr > 0.8% and Mn > 0.8%, in wt%, in an area of 1 mm^2 of a center of a cross-section perpendicular to a longitudinal direction is 5% or less.

[Modes of the Invention]

[0019] Embodiments of the disclosure will now be described. The embodiments of the disclosure, however, may be modified into many different forms and should not be construed as being limited to the embodiments set forth herein. The embodiments of the disclosure are provided to fully convey the idea provided in the disclosure to scope of the invention to those of ordinary skill in the art.

[0020] Terms as herein used are just for illustration. For example, the singular expressions include plural expressions unless the context clearly dictates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0021] Unless otherwise defined, all terms used herein have the same meaning as commonly understood by those of ordinary skill in the art to which the disclosure belongs. Furthermore, unless otherwise clearly defined, a specific term should not be construed as having overly ideal or formal meaning. It is to be understood that the singular expression include plural expressions unless the context clearly dictates otherwise.

[0022] Throughout the specification, the word ’about’, ’substantially’ or the like, is used to indicate that a numerical value used with the word belongs to a range around the numerical value, to prevent an unscrupulous pirate from unduly making an advantage of a description in which the absolute numerical value is mentioned.

[0023] The disclosure provides a wire rod and steel wire for ultrahigh strength spring, and method for manufacturing the same, which may secure high strength and excellent cross-section reduction ratio with a small material deviation after induction (IT) heat treatment through optimization of the content of an element that encourages segregation and a high amount of reduction during continuous casting.

[0024] In an example of the disclosure, a wire rod for ultrahigh strength spring includes, in percent by weight (wt%), 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder having Fe and unavoidable impurities.

[0025] The reason for limiting the alloy composition of the wire rod for ultrahigh strength spring will now be described in detail. The reason for limiting alloy composition of a steel wire for ultrahigh strength spring is the same as that of the wire rod, so the description thereof will be omitted for convenience.

The content of C is 0.5 to 0.7wt%.

[0026] C is an element added to secure strength of the product. When the content of C is less than 0.5wt%, desired strength and Ceq may not be secured. In this case, it may be difficult to secure strength because martensite structure is not completely formed when the steel is cooled, and it may be difficult to secure desired strength even when an intact martensite structure is formed. When the content of C exceeds 0.7wt%, impact property may be degraded and quenching cracks may occur during water cooling.

The content of Si is 0.4 to 0.9wt%.

[0027] Si is an element used for deoxidation of steel, and is an advantageous element to secure strength through solid solution strengthening. In the disclosure, silicon may be added in an amount of 0.4wt% or more to ensure strength. However, when Si is overly added, it may be segregated in the center, causing a difference in hardness between the center and the surface, surface decarburization, and difficulty in processing the material. Considering this, an upper limit of the content of SI may be limited to 0.9 wt% in the disclosure.

The content of Mn is 0.3 to 0.8wt%.

[0028] Mn is a hardenability enhancing element and is one of the essential elements for forming high-strength tempered martensite structure steel. In the disclosure, manganese may be added in an amount of 0.3wt% or more to ensure the strength. However, when Mn is overly added, it may be segregated in the center, causing a difference in hardness between the center and the surface, and is likely to degrade toughness in tempered martensitic steel. Considering this, an upper limit of the content of Mn may be limited to 0.8wt% in the disclosure.

The content of Cr is 0.2 to 0.6wt%.

[0029] Cr, along with Mn, is effective in enhancement of hardenability and enhances strength of tempered martensitic steel. For this, in the disclosure, Cr may be added in an amount of 0.2wt% or more. However, like Si and Mn, Cr is a segregation promoting element, which may bring a risk of causing hardness deviation due to center segregation when overly added. Considering this, an upper limit of the content of Cr may be limited to 0.6wt% in the disclosure.

The content of P is 0.015wt% or less.

[0030] As P is an element that is segregated at grain boundaries to reduce toughness and resistance to hydrogen delayed cracking, it is desirable to exclude it from steel as much as possible. The upper limit may be limited to 0.015wt% in the disclosure.

The content of S is 0.010wt% or less.

[0031] S, like P, is segregated at grain boundaries to reduce toughness, forms MnS to reduce resistance to hydrogen delayed cracking, so it is desirable to exclude it from steel as much as possible. The upper limit may be limited to 0.010wt% in the disclosure.

The content of Al is 0.01wt% or less.

[0032] Al is a strong deoxidizing element, which may increase cleanliness by removing oxygen from steel. On the other hand, when Al is added, it forms Al_2O_3 inclusions and reduces fatigue resistance. Hence, the upper limit may be limited to 0.01wt% in the disclosure.

The content of N is 0.01wt% or less.

[0033] N is combined with Al or V in steel, causing a problem of forming coarse AIN or VN precipitates that are not dissolved during heat treatment. Hence, the upper limit may be limited to 0.01wt% in the disclosure.

The content of O is 0.005wt% or less.

[0034] O may be combined with Al to form coarse inclusions. Hence, the upper limit may be limited to 0.005wt% in the disclosure.

[0035] The remaining component is iron (Fe) in the disclosure. This may not be excluded because unintended impurities may be inevitably mixed from raw materials or surroundings in the normal manufacturing process. These impurities may be known to anyone skilled in the ordinary manufacturing process, so not all of them are specifically mentioned in this specification.

[0036] In the disclosure, segregation on the wire rod in the center is controlled to secure excellent cross-section reduction ratio at high strength after IT heat treatment. For example, a wire rod for ultrahigh strength spring may have 5% or less of a ratio of an area satisfying one or more of C > 0.8%, Si > 0.9%, Cr > 0.8% and Mn > 0.8%, in wt%, in an area of 1 mm^2 of the center of a cross-section perpendicular to the longitudinal direction.

[0037] When the area ratio exceeds 5%, hardness deviation may occur in the cross-section perpendicular to the longitudinal direction after IT heat treatment, which may lead to material deviation, thereby failing to secure a sufficient cross-section reduction ratio at the target strength.

[0038] Furthermore, according to the disclosure, the surface decarburization may be suppressed by low Si alloy composition. For example, a surface ferrite decarburized layer of the wire rod may have a thickness of 1 μm or less. When the thickness of the surface ferrite decarburized layer exceeds 1 μm, an additional process such as carburizing treatment may need to be performed to secure high strength.

[0039] A method of manufacturing a wire rod for ultrahigh strength spring according to the disclosure will now be described in detail. In an example of the disclosure, the wire rod for ultrahigh strength spring is manufactured by preparing a bloom by continuous casting of molten steel having the aforementioned alloy composition, and rolling the bloom into billets and then into wire rods. The respective manufacturing steps will now be described.

[0040] In the disclosure, controlled is the aforementioned ally composition as well as the continuous casting step to minimize center segregation on the wire rod. According to an example, the continuous casting may be performed at a casting speed of 0.48 to 0.54 m/min and may undergo soft reduction with a total amount of reduction of 15 to 35 mm during the continuous casting. The amount of cooling water is appropriately adjusted so that solidification may be completed to a point where soft reduction is completed.

[0041] When the casting speed is too slow, solidification is completed before soft reduction and the ratio of the liquid phase to the solid phase is too low, so it is difficult to secure the effect of removing segregation by soft reduction. On the other hand, when the casting speed is too fast, the ratio of the liquid phase to the solid phase is too high, leading to undesirable formation of segregation due to solidification contraction. Considering this, the casting speed is controlled to be 0.48 to 0.54 m/min in an example of the disclosure.

[0042] When the total amount of reduction is too small during the soft reduction, it is difficult to secure the segregation removal effect by soft reduction. On the other hand, when it is too much, the effect is saturated, and casting equipment is burdened. Considering this, the total amount of reduction of soft reduction is controlled to be 15 to 35 mm/min in an example of the disclosure.

[0043] In an example of the disclosure, soft reduction may be performed so that each role may roll to 4 mm or less and a cumulative amount of reduction is 60% or more when the solidification fraction is 0.6 or more. The solidification fraction refers to a ratio of weight of the molten steel that has become a solid phase to the weight of the whole molten steel.

[0044] The bloom prepared in the aforementioned procedure may be rolled into billets and then into wire rods.

[0045] A method of manufacturing a steel wire for ultrahigh strength spring according to the disclosure will now be described in detail. According to the disclosure, the steel wire for ultrahigh strength spring is manufactured by wire drawing, heating, water cooling at high pressure, tempering, and water cooling a wire rod satisfying the aforementioned alloy composition, having 5% or less of a ratio of an area satisfying one or more of C > 0.8%, Si > 0.9%, Cr > 0.8% and Mn > 0.8%, in wt%, in an area of 1 mm^2 of the center of a cross-section perpendicular to the longitudinal direction. The respective manufacturing steps will now be described.

[0046] In the wire drawing step of the disclosure, the wire rod may be drawn to a wire having diameter of 16 mm or less and manufactured into steel wires to be applied to motorbike suspension springs.

[0047] Subsequently, in the heating step of the disclosure for QT heat treatment of the drawn steel wire, the drawn steel wire may be heated to a quenching temperature of 900 to 1000°C within 10 seconds and then maintained for 5 to 60 seconds to heat-treat the structure of the steel wire to austenite. When the heating time to a target temperature of 900 to 1000°C exceeds 10 seconds, crystal grains grow and makes it difficult to secure desired physical properties. When the holding time is less than 5 seconds, the pearlite structure may not be transformed to the austenite, and when the holding time exceeds 60 seconds, the crystal grains may be coarsened.

[0048] In the disclosure, the step of water cooling at high pressure is a step of transforming the main structure of the steel wire from austenite to martensite, and the water cooling is performed at a pressure as high as to remove the boiling film of the austenitized steel wire in the previous step. In this case, when cooling is performed as oil cooling rather than water cooling, the desired strength may not be secured due to low Ceq. In addition, when the pressure is not as high as to remove the boiling film in the water cooling, a chance of quenching crack increases during quenching, so water cooling is preferably performed as highpressure water cooling by spraying water from all directions at a pressure as high as possible.

[0049] In the disclosure, the tempering step is a step of heating and tempering martensite, which is the main structure of the water-cooled steel wire, into tempered martensite. The tempering step may be heated to 400 to 500°C within 10 seconds and then maintained within 30 seconds. When the tempering temperature is less than 400°C, toughness is not secured, leading to difficulty in processing and increasing the risk of the product breaking, and when the temperature exceeds 500°C, strength is reduced, so the tempering temperature is limited to the above temperature range. In addition, when it is not heated to the above temperature range within 10 seconds for tempering, coarse carbides are formed and toughness is likely to deteriorate, so it is desirable to rapidly heat within 10 seconds.

[0050] In the disclosure, for heating, a means for heating to the quenching temperature and a means for tempering use IT heat treatment to sufficiently harden the surface during subsequent water cooling by rapid heating.

[0051] Thereafter, the tempered steel wire is water-cooled to room temperature to manufacture a steel wire for an ultrahigh strength spring.

[0052] In an example of the disclosure, a steel wire for ultrahigh strength spring includes, in wt%, 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder including Fe and unavoidable impurities, and for area fraction, 90% or more of tempered martensite, wherein a ratio of an area satisfying one or more of C > 0.8%, Si > 0.9%, Cr > 0.8% and Mn > 0.8%, in wt%, in an area of 1 mm^2 of a center of a cross-section perpendicular to the longitudinal direction may be 5% or less.

[0053] In addition, the steel wire for an ultrahigh strength spring in an example of the disclosure may have a hardness deviation of 25 Hv or less in other area than an area having a depth of 0.5 mm or less from the outermost surface in a cross-section perpendicular to the longitudinal direction. When the hardness deviation exceeds 25 Hv, a sufficient cross-section reduction ratio may not be secured.

[0054] In addition, the steel wire for an ultrahigh strength spring in an example of the disclosure may have a tensile strength of 1750 to 2200 MPa and a cross-section reduction ratio of 40% or more.

[0055] The disclosure will now be described in more detail in the following embodiment of the disclosure. The following embodiment, however, is an illustrative example to describe the disclosure in more detail, and should not be construed as limiting the scope of the disclosure. The scope of the disclosure is defined by the claims and their equivalents.

{Embodiment}

[0056] The molten steel having the alloy composition of Table 1 below was cast into a bloom at the casting speed and total amount of soft reduction of Table 2, and then manufactured into a wire rod having a diameter of 9 mm through billet rolling and wire rod rolling.

[0057] Segregation areas in Table 2 were derived by analyzing with an electron probe micro analyzer (EPMA) in a center area of 1 mm^2 of the cross-section perpendicular to the longitudinal direction of the manufactured wire rod. 'C segregation area' in Table 2 refers to a ratio of an area satisfying C > 0.8wt% in the center area of 1 mm^2 of the cross-section perpendicular to the longitudinal direction. 'Si segregation area' refers to a ratio of an area satisfying Si > 0.9wt% in the center area of 1 mm^2 of the cross-section perpendicular to the longitudinal direction. 'Cr segregation area' refers to a ratio of an area satisfying Cr > 0.8wt% in the center area of 1 mm^2 of the cross-section perpendicular to the longitudinal direction. 'Mn segregation area' refers to a ratio of an area satisfying Mn > 0.8wt% in the center area of 1 mm^2 of the cross-section perpendicular to the longitudinal direction.

[Table 1]

	alloy composition (wt%)								
	C	Si	Mn	Cr	P	S	Al	O	N
Comparati ve example 1	0.55	1.41	1.01	0.65	0.011	0.004	<0.003	<0.005	<0.01
Comparati ve example 2	0.56	0.25	0.75	0.75	0.01	0.005	<0.003	<0.005	<0.01
Comparati ve example 3	0.61	0.79	0.63	0.55	0.01	0.004	<0.003	<0.005	<0.01
Inventive example 1	0.58	0.78	0.62	0.43	0.009	0.005	<0.003	<0.005	<0.01
Inventive example 2	0.62	0.61	0.41	0.52	0.011	0.005	<0.003	<0.005	<0.01

[Table 2]

	Casting speed (m/min)	total amount of soft reduction (mm)	C segregation area (%)	Si segregation area (%)	Mn segregation area (%)	Cr segregation area (%)
Comparativ e example 1	0.50	25	< 1	5.4	6.2	< 1
Comparativ e example 2	0.52	25	< 1	1.2	< 1	< 1
Comparativ e example 3	0.56	10	12	13	11	12
Inventive example 1	0.52	25	< 1	< 1	< 1	< 1
Inventive example 2	0.52	25	< 1	< 1	< 1	< 1

[0058] Thereafter, the wire rods in Table 1 were manufactured into steel wires having a diameter of 8 mm, and heat treatment was performed under the conditions shown in Table 3 below. The austenitizing heat treatment-high pressure water cooling-tempering-water cooling were performed in sequence. The hardness deviation refers to one when the hardness was measured at 10 points or more in other area than the area having a depth of 0.5 mm or less from the outermost surface in the cross-section perpendicular to the longitudinal direction.

[Table 3]

	austenitizing temperature (°C)	tempering temperature (°C)	hardness deviation (Hv)	cross-section reduction ratio (%)	tensile strength (MPa)
Comparativ e example 1	950	430	35.2	38	2,020
Comparativ e example 2	950	430	12.1	48	1,710
Comparativ e example 3	950	430	45.1	25	1,801
Inventive example 1	950	430	18.1	48	1,820
Inventive example 2	950	430	10.1	47	1,790

[0059] Referring to Tables 1, 2, and 3, the inventive examples 1 and 2 satisfying the alloy composition and manufacturing conditions of the disclosure satisfied hardness deviation of 25 Hv or less, tensile strength of 1750 to 2200 MPa, and a cross-section reduction ratio of 40% or more in the other area than the area having a depth of 0.5 mm or less from the outermost surface in a cross-section perpendicular to the longitudinal direction after IT heat treatment. On the other hand, in the comparative example 1, Si and Mn contents were high, causing hardness deviation due to Si and Mn segregation in the center, so the cross-section reduction ratio was 40% or less.

[0060] The comparative example 2 did not secure the target tensile strength due to the low Si content.

[0061] In the comparative example 3, center segregation occurred due to too fast a casting speed and insufficient amount of soft reduction, and as a result, the hardness deviation increased and the cross-section reduction ratio was 40% or less.

[0062] Embodiments of the disclosure have thus far been described, but the disclosure is not limited thereto, and it will be obvious to those of ordinary skill in the art that various modifications and alterations can be made without deviating from the scope of the appended claims.

[Industrial Applicability]

[0063] According to an example of the disclosure, a high-quality wire rod and steel wire for ultrahigh strength spring, and method for manufacturing the same, capable of securing high strength and high cross-section reduction ratio with small material deviation after induction heat treatment.

Claims

1. A wire rod for ultrahigh strength spring, the wire rod comprising:

   in percent by weight (wt%), 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder having Fe and unavoidable impurities,
   wherein a ratio of an area satisfying one or more of C > 0.8%, Si > 0.9%, Cr > 0.8% and Mn > 0.8%, in wt%, in an area of 1 mm^2 of a center of a cross-section perpendicular to a longitudinal direction is 5% or less.

2. The wire rod for ultrahigh strength spring of claim 1, further comprising: a surface ferrite decarburized layer having a thickness of 1 μm or less.

3. A method of manufacturing a wire rod for ultrahigh strength spring, the method comprising:

   preparing a bloom by continuous casting of molten steel including, in wt%, 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder having Fe and unavoidable impurities; and
   rolling the bloom into billets and then into wire rods,
   wherein the continuous casting is performed at a casting speed of 0.48 to 0.54 m/min and comprises soft reduction with a total amount of reduction of 15 to 35 mm during the continuous casting.

4. The method of claim 3, wherein the soft reduction is performed so that each roll rolls to 4 mm or less and a cumulative amount of reduction is 60% or more when the solidification fraction is 0.6 or more.

5. A steel wire for ultrahigh strength spring, the steel wire comprising:

   in percent by weight (wt%), 0.5 to 0.7% of C, 0.4 to 0.9% of Si, 0.3 to 0.8% of Mn, 0.2 to 0.6% of Cr, 0.015% or less of P, 0.010% or less of S, 0.01% or less of Al, 0.01% or less of N, 0.005% or less of O, and the remainder having Fe and unavoidable impurities, and
   for area fraction, 90% or more of tempered martensite,
   wherein a ratio of an area satisfying one or more of C > 0.8%, Si > 0.9%, Cr > 0.8% and Mn > 0.8%, in wt%, in an area of 1 mm^2 of a center of a cross-section perpendicular to a longitudinal direction is 5% or less.

6. The steel wire for ultrahigh strength spring of claim 5, wherein the steel wire has a hardness deviation of 25 Hv or less in the cross-section perpendicular to the longitudinal direction except for an area having a depth of 0.5 mm or less from the outermost surface.

7. The steel wire for ultrahigh strength spring of claim 5, wherein the steel wire has a tensile strength of 1750 to 2200 MPa and a cross-section reduction ratio of 40% or more.

8. A method of manufacturing a steel wire for ultrahigh strength spring, the method comprising:

   drawing the wire rod of claim 1;
   heating at 900 to 1000°C within 10 seconds;
   water cooling at high pressure;
   heating and tempering at 400 to 500°C within 10 seconds; and
   water cooling.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2021/016993

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/18(2006.01)i; **C21D 9/52**(2006.01)i; **C21D 8/06**(2006.01)i; **B21B 1/16**(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 38/18(2006.01); C21D 8/06(2006.01); C21D 9/60(2006.01); C22C 38/00(2006.01); C22C 38/02(2006.01); C22C 38/04(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: 스프링(spring), 선재(wire rod), 고강도(high strength), 연속주조(continuous casting), 탈탄층(decarburization layer), 템퍼드 마르텐사이트(tempered martensite), 편석(segregation)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2019-178405 A (JFE STEEL CORP.) 17 October 2019 (2019-10-17) See paragraphs [0001] and [0035]-[0036], claim 1 and table 2.	1-8
Y	CN 110760748 A (BAOSHAN IRON & STEEL CO., LTD.) 07 February 2020 (2020-02-07) See paragraph [0038].	1-8
Y	KR 10-2018-0072965 A (POSCO) 02 July 2018 (2018-07-02) See paragraphs [0123]-[0124] and [0126] and claims 16 and 19.	5-8
A	KR 10-2015-0081366 A (KABUSHIKI KAISHA KOBE SEIKO SHO (KOBE STEEL, LTD.)) 13 July 2015 (2015-07-13) See paragraphs [0093]-[0103] and claims 1 and 4.	1-8
A	KR 10-0398384 B1 (POHANG IRON & STEEL CO., LTD.) 18 December 2003 (2003-12-18) See claim 1.	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
"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	Date of mailing of the international search report
20 April 2022	**20 April 2022**

Name and mailing address of the ISA/KR	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2021/016993

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REFERENCES CITED IN THE DESCRIPTION

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