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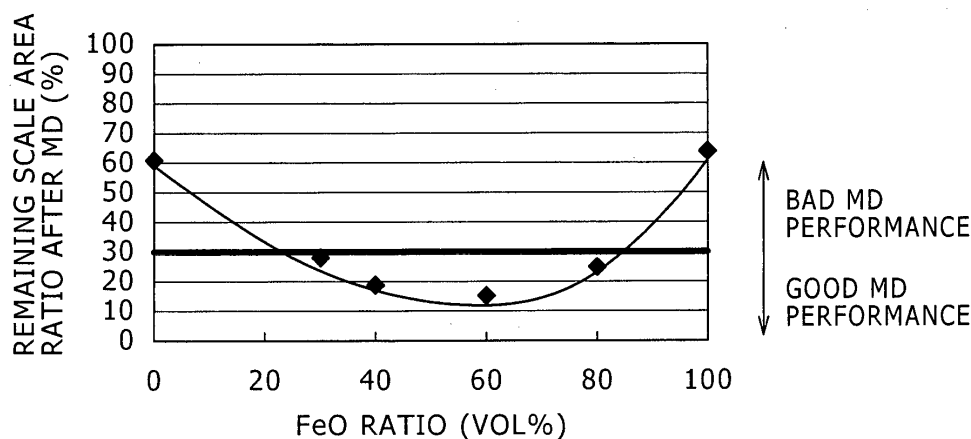
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(54) **STEEL WIRE MATERIAL AND METHOD FOR PRODUCING SAME**

(57) The steel wire material of the present invention contains 0.05 to 1.2% of C (mass%; same for the chemical components hereafter), 0.01 to 0.5% of Si, 0.1 to 1.5% of Mn, 0.02% or less (but not 0%) of P, 0.02% or less (but not 0%) of S, and 0.005% or less (but not 0%) of N, with the balance being iron and inevitable impurities.

The wire material has a scale layer that is no thicker than 7.0 μm or less. The scale layer has an FeO percentage of 30 to 80 vol% and an Fe₂SiO₄ percentage of less than 0.1 vol%. The scale layer that is formed will not peel when cooled after hot rolling or during storage and transport, but will easily peel during mechanical descaling.

FIG. 1



Description

[Technical Field]

[0001] The present invention relates to a steel wire material and a method for manufacturing the same, and relates more specifically to a hot rolled steel wire material (hereinafter simply referred to as "wire material") formed with a thin scale not peeling off during cooling after hot rolling and at the time of storage and transportation and easily removable by mechanical descaling, and a method for manufacturing the same.

[Background Art]

[0002] A scale is formed normally on the surface of a wire material manufactured by hot rolling, and it is required to remove the scale before subjecting the wire material to secondary work such as drawing and the like. As such a scale removing method before secondary work, a batch type acid cleaning method was employed in prior arts, however, in recent years, from the viewpoints of the environmental pollution and cost reduction, a mechanical descaling (hereinafter referred to as MD) method has come to be employed. Therefore, the wire material is required to be formed with a scale with excellent MD performance.

[0003] As methods for manufacturing a wire material formed with a scale with excellent MD performance, Patent Literatures 1-5 can be cited for example. In Patent Literatures 1, 2, the scale amount remaining in the wire material after MD is reduced by forming a scale which is high in FeO ratio and thick. In Patent Literature 3, by lowering the boundary face roughness, propagation of the crack occurring on the boundary face of the scale is promoted, and the remaining scale amount is reduced. In Patent Literatures 4, 5, by controlling the area ratio of the holes inside the scale, the peeling performance of the scale is improved.

[0004] However, Patent Literatures 1-5 described above have problems as described below. According to the method of forming the scale thick as Patent Literatures 1, 2, drop of the yield is caused, the scale peels off during the cooling step and at the time of storage and transportation, and the rust is generated. Also, when the scale is thick, even when a bending strain is applied to the wire material by the MD method and the wire material surface is subjected to brushing, it is difficult to perfectly remove the scale. More specifically, according to the MD method, unlike the batch type acid cleaning method, it is difficult to remove the entire scale evenly and stably, and even when the wire material formed with thick scale is subjected to MD, the surface of the wire material may occasionally be spotted with finely crushed scale powder. When the remaining scale remaining locally thus increases, in the secondary work such as drawing and the like, problems such as occurrence of a flaw due to the defective lubrication, lowering of the lifetime of the dice and the like are caused.

[0005] Also, it is difficult to stably lower the boundary face roughness by the method of lowering the boundary face roughness such as Patent Literature 3, it is difficult to stably form the holes even by the method of forming holes inside the scale such as Patent Literatures 4, 5, and it is difficult to stably reduce the remaining scale amount according to either of these technologies.

[0006] Further, in these Patent Literatures 1-5, peeling off of the scale due to the compression stress generated during cooling is not considered at all, and there was a problem that the rust was generated in the wire material before MD by peeling off of the scale during cooling and at the time of storage and transportation.

[Citation List]

[Patent Literature]

[0007]

[Patent Literature 1] Japanese Unexamined Patent Application Publication No. H4-293721

[Patent Literature 2] Japanese Unexamined Patent Application Publication No. H11-172332

[Patent Literature 3] Japanese Unexamined Patent Application Publication No. H8-295992

[Patent Literature 4] Japanese Unexamined Patent Application Publication No. H10-324923

[Patent Literature 5] Japanese Unexamined Patent Application Publication No. 2006-28619

[Summary of Invention]

[Technical Problems]

[0008] The present invention has been developed in view of the circumstances described above, and its object is to

provide a wire material formed with a scale not peeling off during cooling after hot rolling and at the time of storage and transportation and easily peeling off at the time of MD, and a method for manufacturing the same.

[Solution to Problems]

[0009] The steel wire material of the present invention which solved the problems described above is a steel wire material containing C: 0.05-1.2% ("% means "% by mass", hereinafter the same for chemical components), Si: 0.01-0.5%, Mn: 0.1-1.5%, P: 0.02% or less (not including 0%), S: 0.02% or less (not including 0%), and N: 0.005% or less (not including 0%), with the remainder being iron and unavoidable impurities, in which a scale with 7.0 μm or less thickness is included, FeO ratio inside the scale is 30-80 vol%, and Fe_2SiO_4 ratio is less than 0.1 vol%.

[0010] According to the necessity, the steel wire material of the present invention may also contain (a) Cr: 0.3% or less (not including 0%) and/or Ni: 0.3% or less (not including 0%), (b) Cu: 0.2% or less (not including 0%), (c) at least one element selected from a group consisting of Nb, V, Ti, Hf and Zr by 0.1% or less (not including 0%) in total, (d) Al: 0.1% or less (not including 0%), (e) B: 0.005% or less (not including 0%), and (f) Ca: 0.01% or less (not including 0%) and/or Mg: 0.01% or less (not including 0%).

[0011] Further, the present invention also includes a method for manufacturing a steel wire material including a step of hot rolling steel of any of the chemical compositions described above, a step of thereafter winding up the hot rolled steel at 750-880°C, and a step of cooling the wound steel while injecting a gas mixture of oxygen and an inert gas whose oxygen fraction is less than 20 vol% or an inert gas. It is preferable that the inert gas is nitrogen.

[Advantageous Effects of Invention]

[0012] In the steel wire material of the present invention, the FeO ratio is appropriately controlled to a predetermined range (30-80 vol%), and a thin (7 μm or less) scale is included. Accordingly, the scale does not peel off during cooling after hot rolling and at the time of storage and transportation, and generation of the rust can be prevented. Further, according to the present invention, because the scale easily peels off at the time of MD, sufficient peeling performance can be secured with a simple descaling device, adverse effects (a flaw on the surface of the wire material, defective lubrication and the like due to leaving the scale unremoved) are not exerted in secondary work such as drawing and the like, and the steel wire material of high quality can be provided. Also, because the scale loss is less, high yield can be maintained.

[Brief Description of Drawings]

[0013]

[Fig. 1] Fig. 1 is a graph showing the relation between the FeO ratio inside the scale and the remaining scale area ratio after MD.

[Fig. 2] Fig. 2 is a graph showing the relation between the scale thickness and the scale peeling ratio of the rolled material.

[Description of Embodiments]

[0014] In a cooling step during a manufacturing process of a wire material, normally, a compression stress is generated inside the scale due to the difference in the coefficient of thermal expansion between the base iron and the scale. As a result, the scale naturally peels off during the cooling step or at the time of storage and transportation of the wire material thereafter, which became the cause of generation of the rust. Also, the scale is removed by MD before executing secondary work such as drawing and the like, and the lifetime of the dice is shortened when the scale remains after MD. Therefore, the wire material having a scale that does not peel off in the cooling step during the manufacturing process and at the time of storage and transportation and easily peels off at the time of MD has been desired.

[0015] The MD method is a method for making the scale peel off by applying strain to the wire material to generate cracks inside the scale or in the boundary face of the base iron and the scale. Conventionally, increase of the FeO ratio inside the scale has been executed in order to improve the peeling performance of the scale. This is because the increase of the FeO ratio inside the scale is considered to be effective in improving the peeling performance of the scale at the time of MD because the strength of FeO is weaker than Fe_2O_3 and Fe_3O_4 . In order to increase the FeO ratio inside the scale, it is normally required to form a scale (a secondary scale formed in or after descaling before finish rolling) at a high temperature, however there was a problem that, when the scale was formed at a high temperature, the thickness of the scale increased, the scale loss increased, and the thick scale peeled off during the cooling step and at the time of storage and transportation. In other words, it was extremely difficult to make the thickness of the scale thin

and to secure the FeO ratio inside the scale.

[0016] So, as a result of studies by the present inventors, it was found out that, when the winding temperature after the hot rolling was made comparatively low temperature and cooling was thereafter executed while injecting a gas mixture of oxygen and an inert gas whose oxygen fraction was comparatively low or an inert gas, the scale could be made thin and the FeO ratio inside the scale could be secured by a predetermined ratio or more.

[0017] When the thickness of the scale was studied in more detail, it was found out that, if the thickness of the scale was 7.0 μm or less, adhesiveness against the base iron was excellent, and the scale did not peel off in the middle of cooling and at the time of storage and transportation. The scale thickness is preferably 6.5 μm or less, more preferably 6.0 μm or less (particularly 5.5 μm or less). Although the lower limit of the scale thickness is not particularly limited, it is approximately 0.9 μm normally.

[0018] Further, the present inventors investigated the relation between the FeO ratio inside the scale and the MD performance. More specifically, the wire material with 200 mm length having a composition of 0.9% C-0.25% Si-0.86% Mn-0.007% P-0.0063% S-0.002% N was used, the winding temperature condition was changed, and the samples whose composition of the scale was adjusted were manufactured. Also, the winding temperature was changed in the range of 700-1,000°C, and N₂-10 vol% O₂ gas was used for cooling after winding. The scale was made peel off by applying a deformation strain (6%) equivalent to MD to the manufactured sample, and the scale amount (area ratio) remained was measured by image analysis similarly to the example described below. Fig. 1 is a graph showing the relation between the FeO ratio inside the scale and the area ratio of the scale that remained after MD.

[0019] According to Fig. 1, it is known that, when the FeO ratio inside the scale is 30-80 vol%, the remaining scale amount after MD can be reduced sufficiently. The FeO ratio is preferably 35 vol% or more and 75 vol% or less, more preferably 40 vol% or more and 70 vol% or less, and further more preferably 45 vol% or more and 65 vol% or less.

[0020] Also, the Fe₂SiO₄ (fayalite) ratio inside the scale is to be less than 0.1 vol%. When excessively formed, Fe₂SiO₄ is formed unevenly on the boundary face between the scale and the base iron, the scale unevenly peels off at the time of MD, and therefore the MD performance deteriorates. The Fe₂SiO₄ ratio is preferably 0.09 vol% or less, more preferably 0.08 vol% or less, and further more preferably 0.07 vol% or less. On the other hand, since Fe₂SiO₄ inside the scale is an oxide that is brittle and easily peels off and is formed evenly and thin if its amount is slight, it has an action of improving the MD performance. In order to exert such action effectively, it is preferable to secure Fe₂SiO₄ by 0.01 vol% or more, more preferably 0.02 vol% or more, and further more preferably 0.03 vol% or more.

[0021] In the scale in the present invention, Fe₂O₃, Fe₃O₄ and the like are included other than FeO and Fe₂SiO₄.

[0022] By making the thickness of the scale and the area ratio of the fine holes as described above, the remaining scale amount after MD can be made 30% or less by the area ratio relative to the scale amount before MD. This is equivalent to approximately 0.05 mass% or less in terms of the remaining scale amount relative to the mass of the steel wire material. The remaining scale amount is preferably 25% or less by area, more preferably 20% or less by area.

[0023] In order to form the scale described above, it is important to hot-roll the steel with the chemical composition described below, to thereafter execute winding at a comparatively low temperature (750-880°C), and then to execute cooling while injecting a gas mixture of oxygen and an inert gas whose oxygen fraction is low or an inert gas. By executing winding at a low temperature, the scale can be made thin. Also, by injecting the gas whose oxygen fraction is low or not including oxygen as described above and executing cooling, FeO can be secured by a predetermined amount or more without converting FeO formed to Fe₃O₄.

[0024] When the winding temperature after hot rolling exceeds 880°C, the scale thickness exceeds 7.0 μm , the FeO ratio inside the scale exceeds 80 vol%, and the MD performance deteriorates. Also, when the winding temperature exceeds 880°C, Fe₂SiO₄ (fayalite) possibly exceeds 0.1 vol% and is formed unevenly on the boundary surface between the scale and the base iron, the scale peels off unevenly at the time of MD, and the MD performance deteriorates. On the other hand, when the winding temperature is below 750°C, 30 vol% or more of the FeO ratio cannot be secured, and the MD performance deteriorates. The winding temperature is preferably 770°C or above and 875°C or below, more preferably 790°C or above and 860°C or below.

[0025] Cooling after hot rolling is executed while injecting a gas mixture of oxygen and an inert gas whose oxygen fraction is less than 20 vol% or an inert gas. By cooling while injecting such a gas with low oxygen fraction or not containing oxygen, FeO already formed can be prevented from being converted to Fe₃O₄, and the FeO ratio inside the scale can be secured. The oxygen fraction is preferably 10 vol% or less, more preferably 5 vol% or less, and further more preferably 0 vol% (that is, the inert gas only). Argon, nitrogen and the like can be cited as the inert gas, and nitrogen is preferable. Although the cooling stopping temperature in cooling executed while injecting the gas described above is not particularly limited, cooling may be executed to approximately 550-650°C for example while injecting the gas described above, and cooling may be executed thereafter to the room temperature in the atmospheric air.

[0026] Below, the chemical composition of the steel wire material of the present invention will be described.

C: 0.05-1.2%

[0027] C is an element greatly affecting the mechanical properties of steel. In order to secure the strength of the wire material, the C amount was stipulated to be 0.05% or more. The C amount is preferably 0.15% or more, more preferably 0.3% or more. On the other hand, when the C amount is excessively high, the hot workability in manufacturing the wire material deteriorates. Therefore, the C amount was stipulated to be 1.2% or less. The C amount is preferably 1.1% or less, more preferably 1.0% or less.

Si: 0.01-0.5%

[0028] Si is an element required for deoxidizing steel. When its content is too low, formation of Fe_2SiO_4 (fayalite) becomes insufficient, and the MD performance deteriorates. Therefore, the Si amount was stipulated to be 0.01% or more. The Si amount is preferably 0.1% or more, more preferably 0.2% or more. On the other hand, when the Si amount is excessively high, by excessive formation of Fe_2SiO_4 (fayalite), such problems occur that the MD performance extremely deteriorates, a surface decarburized layer is formed, and the like. Therefore, the Si amount was stipulated to be 0.5% or less. The Si amount is preferably 0.45% or less, more preferably 0.4% or less.

Mn: 0.1-1.5%

[0029] Mn is an element useful in securing the quenchability of steel and increasing the strength. In order to effectively exert such actions, the Mn amount was stipulated to be 0.1% or more. The Mn amount is preferably 0.2% or more, more preferably 0.4% or more. On the other hand, when the Mn amount is excessively high, segregation occurs in the cooling step after the hot rolling, and super-cooled structure (martensite and the like) harmful for the drawability and the like is liable to be generated. Therefore, the Mn amount was stipulated to be 1.5% or less. The Mn amount is preferably 1.4% or less, more preferably 1.2% or less.

P: 0.02% or less (not including 0%)

[0030] P is an element deteriorating the toughness and ductility of steel. In order to prevent the wire breakage in the drawing step and the like, the P amount was stipulated to be 0.02% or less. The P amount is preferably 0.01% or less, more preferably 0.005% or less. Although the lower limit of the P amount is not particularly limited, it is approximately 0.001% normally.

S: 0.02% or less (not including 0%)

[0031] Similarly to P, S is an element deteriorating the toughness and ductility of steel. In order to prevent the wire breakage in the drawing step and the twisting step thereafter, the S amount was stipulated to be 0.02% or less. The S amount is preferably 0.01% or less, more preferably 0.005% or less. Although the lower limit of the S amount is not particularly limited, it is approximately 0.001% normally.

N: 0.005% or less (not including 0%)

[0032] N is an element deteriorating the ductility of steel when the content thereof becomes excessively high. Therefore, the N amount was stipulated to be 0.005% or less. The N amount is preferably 0.004% or less, more preferably 0.003% or less. Although the lower limit of the N amount is not particularly limited, it is approximately 0.001% normally.

[0033] The fundamental composition of the steel wire material of the present invention is as described above, and the balance is substantially iron. However, inclusion of unavoidable impurities brought in due to situations of raw materials, materials, manufacturing facilities and the like in the steel wire material is allowed as a matter of course. Further, it is also recommended to add elements described below according to the necessity within a range not impeding the actions and effects of the present invention.

Cr: 0.3% or less (not including 0%) and/or Ni: 0.3% or less (not including 0%)

[0034] Both of Cr and Ni are elements enhancing the quenchability of steel and contributing to increase the strength. In order to exert such actions effectively, the Cr amount is preferably 0.05% or more and the Ni amount is preferably 0.03% or more. Both of the Cr amount and Ni amount are more preferably 0.10% or more, and further more preferably 0.12% or more. On the other hand, when the Cr amount and Ni amount are excessively high, the martensite structure is liable to be generated, adhesiveness of the scale and the base iron increases excessively high, and the peeling

performance of the scale at the time of MD deteriorates. Therefore, both of the Cr amount and Ni amount are preferably 0.3% or less, more preferably 0.25% or less, and further more preferably 0.20% or less.

Cu: 0.2% or less (not including 0%)

[0035] Cu is an element having an action of promoting peeling of the scale. In order to exert such action effectively, the Cu amount is preferably 0.01% or more, more preferably 0.05% or more, and further more preferably 0.10% or more. On the other hand, when the Cu amount is excessively high, peeling of the scale is promoted excessively, the scale peels off during rolling, other scales which are thin and highly adhesive are generated on the peeled surface, and the rust is generated when the wire material coil is stored and transported. Therefore, the Cu amount is preferably 0.2% or less, more preferably 0.17% or less, and further more preferably 0.15% or less.

At least one element selected from a group consisting of Nb, V, Ti, Hf and Zr: 0.1% or less (not including 0%) in total

[0036] All of Nb, V, Ti, Hf and Zr are elements forming fine carbonitride and contributing to increase the strength. In order to exert such actions effectively, all of the Nb amount, V amount, Ti amount, Hf amount and Zr amount are preferably 0.003% or more, more preferably 0.007% or more, and further more preferably 0.01% or more. On the other hand, when these elements are excessively high, the ductility deteriorates, and therefore the total amount thereof is preferably 0.1% or less, more preferably 0.08% or less, and further more preferably 0.06% or less.

Al: 0.1% or less (not including 0%)

[0037] Al is an element effective as a deoxidizing agent. In order to exert such action effectively, the Al amount is preferably 0.001% or more, more preferably 0.005% or more, and further more preferably 0.01% or more. On the other hand, when the Al amount is excessively high, oxide-based inclusions such as Al_2O_3 and the like increase, and wire breakage frequently occurs in drawing work and the like. Therefore, the Al amount is preferably 0.1% or less, more preferably 0.08% or less, and further more preferably 0.06% or less.

B: 0.005% or less (not including 0%)

[0038] B is an element suppressing formation of ferrite by being present as free B (B that does not form the compound) solid-solved in steel, and is an element effective particularly in a high strength wire material which requires suppression of a longitudinal crack. In order to exert such actions effectively, the B amount is preferably 0.0001% or more, more preferably 0.0005% or more, and further more preferably 0.0010% or more. On the other hand, when the B amount is excessively high, the ductility deteriorates. Therefore, the B amount is preferably 0.005% or less, more preferably 0.0040% or less, and further more preferably 0.0035% or less.

Ca: 0.01% or less (not including 0%) and/or Mg: 0.01% or less (not including 0%)

[0039] Both of Ca and Mg are elements having an action of controlling the form of the inclusions and enhancing the ductility. Further, Ca also has an action of enhancing the corrosion resistance of the steel material. In order to exert such actions effectively, both of the Ca amount and the Mg amount are preferably 0.001% or more, more preferably 0.002% or more, and further more preferably 0.003% or more. On the other hand, when these elements are excessively high, the workability deteriorates. Therefore, both of the Ca amount and the Mg amount are preferably 0.01% or less, more preferably 0.008% or less, and further more preferably 0.005% or less.

[Example]

[0040] Below, the present invention will be explained more specifically referring to an example. The present invention is not limited by the example described below, and it is a matter of course that the present invention can also be implemented with modifications being added appropriately within the scope adaptable to the purposes described above and below, and any of them is to be included within the technical range of the present invention.

[0041] After steel of the chemical composition shown in Tables 1, 2 was smelted according to an ordinary smelting method, a billet of 150 mm×150 mm was manufactured and was heated inside a heating furnace. Thereafter, the primary scale formed inside the heating furnace was descaled using high-pressure water, hot rolling was executed under the conditions (the winding temperature after hot rolling and the gas used for cooling) shown in Table 3, and the steel wire material of $\Phi 5.5$ mm was obtained. Also, cooling using the gas shown in Table 3 was executed to approximately 600°C in all cases, and the wire material was left for cooling in the atmospheric air.

[0042] The obtained steel wire material was measured by a method described below.

(1) Measurement of thickness of scale

[0043] Samples with 10 mm length were taken from the front end, center part and rear end of the coil respectively, and the cross sections of the scale of optional three locations from each sample were observed using a scanning electron microscope (SEM) (observation magnification: 5,000 times). The scale thickness was measured for 10 points at every 100 μm length in the peripheral direction of the steel wire material on each measurement location, the average scale thickness thereof was obtained, and the average value of the three locations was made the scale thickness of each sample. Further, the average value of respective samples (the front end, center part and rear end of the coil) was calculated, and was made the scale thickness of each test No.

(2) Measurement of composition of scale

[0044] Similarly to above (1), samples with 10 mm length were taken from the front end, center part and rear end of the coil respectively, X-ray diffraction was performed for the cross sections of the scale of optional three locations from each sample, and the ratios (vol%) of FeO and Fe_2SiO_4 were obtained from the peak intensity ratio of FeO, Fe_2SiO_4 , Fe_2O_3 and Fe_3O_4 . The average values of the three locations were made the FeO ratio and the Fe_2SiO_4 ratio of each sample. Further, the average value of respective samples (the front end, center part and rear end of the coil) was calculated, and was made the FeO ratio and the Fe_2SiO_4 ratio of each test No.

(3) Measurement of scale peeling performance of rolled material

[0045] Samples with 200 mm length were taken from the front end, center part and rear end of the coil respectively, air was blown to the sample, and the scale on the surface of the steel wire material was blown out. The appearance before and after blowing the air was photographed by a digital camera, and the area ratio of the scale having peeled off was obtained by comparing the both by image analysis.

(3) Measurement of MD performance

[0046] Samples with 250 mm length were taken from the front end, center part and rear end of the coil respectively, were applied with deformation strain of 6% by a tensile test machine, and were taken out from the chuck. Air was thereafter blown to the sample, and the scale on the surface of the steel wire material was blown out. The appearance before and after application of the strain was photographed by a digital camera, and the area ratio of the remaining scale was calculated by comparing the both by image analysis.

[0047] The results are shown in Tables 4, 5 and Fig. 2.

[0048]

[Table 1]

Steel kind	Chemical composition (mass%) with the remainder being iron and unavoidable impurities											
	C	Si	Mn	P	S	N	Cr	Ni	Cu	Al	B	Others
A-1	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	-	-	-
A-2	0.80	0.25	0.55	0.007	0.003	0.002	0.28	-	-	-	-	-
A-3	0.80	0.25	0.55	0.007	0.003	0.002	-	0.23	-	-	-	-
A-4	0.80	0.25	0.55	0.007	0.003	0.002	-	-	0.18	-	-	-
A-5	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	0.025	-	-
A-6	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	-	0.0005	-
A-7	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	-	-	V=0.035
A-8	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	-	-	Ca=0.004
A-9	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	-	-	Hf=0.052
A-10	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	-	-	Ti=0.038
A-11	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	-	-	Mg=0.003

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(continued)

Steel kind	Chemical composition (mass%) with the remainder being iron and unavoidable impurities											
	C	Si	Mn	P	S	N	Cr	Ni	Cu	Al	B	Others
A-12	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	-	-	Nb=0.031
A-13	0.80	0.25	0.55	0.007	0.003	0.002	-	-	-	-	-	Zr=0.056
A-14	0.80	0.25	0.55	0.007	0.003	0.002	0.23	0.03	-	-	-	-
A-15	0.80	0.25	0.55	0.007	0.003	0.002	0.14	0.13	0.07	-	-	-
A-16	0.80	0.25	0.55	0.007	0.003	0.002	0.05	0.09	-	0.011	-	-
A-17	0.80	0.25	0.55	0.007	0.003	0.002	0.12	0.25	-	-	0.0011	-
A-18	0.80	0.25	0.55	0.007	0.003	0.002	0.08	0.08	-	-	-	Ti=0.072
A-19	0.80	0.25	0.55	0.007	0.003	0.002	0.05	-	0.05	-	-	-
A-20	0.80	0.25	0.55	0.007	0.003	0.002	0.16	-	0.14	0.028	-	-
A-21	0.80	0.25	0.55	0.007	0.003	0.002	-	0.15	0.09	-	-	-
A-22	0.80	0.25	0.55	0.007	0.003	0.002	-	0.28	0.17	0.035	-	-
A-23	0.80	0.25	0.55	0.007	0.003	0.002	-	0.12	0.06	-	0.0009	-
A-24	0.80	0.25	0.55	0.007	0.003	0.002	-	0.07	0.15	-	-	Hf=0.054

[0049]

[Table 2]

Steel kind	Chemical composition (mass%) with the remainder being iron and unavoidable impurities											
	C	Si	Mn	P	S	N	Cr	Ni	Cu	Al	B	Others
B	0.06	0.08	0.12	0.003	0.005	0.002	0.12	0.03	-	0.01	-	V=0.029
C	0.19	0.17	0.42	0.003	0.001	0.002	-	-	0.04	0.021	-	-
D	0.44	0.38	0.88	0.002	0.003	0.002	-	-	-	-	-	Ca=0.002
E	0.69	0.45	0.76	0.002	0.004	0.002	-	0.01	0.02	-	0.0005	Ti=0.031,Hf=0.027
F	0.88	0.37	0.46	0.002	0.003	0.002	0.27	-	0.03	0.015	-	-
G	0.92	0.48	0.98	0.002	0.003	0.002	0.18	0.23	0.02	-	-	Ca=0.003
H	1.05	0.29	1.15	0.004	0.003	0.002	0.26	0.02	0.16	0.002	0.0021	Ti=0.026,Hf=0.022
I	1.19	0.32	1.32	0.002	0.001	0.002	0.03	0.14	0.12	0.001	0.0034	Zr=0.027,Nb=0.043

[0050]

[Table 3]

Manufacturing condition	Winding temperature (°C)	Cooling gas composition
a	750	Nitrogen
b	760	Atmospheric air
c	800	Nitrogen + 1 vol% oxygen
d	850	Nitrogen + 5 vol% oxygen
e	875	Nitrogen + 10 vol% oxygen
f	880	Atmospheric air
g	890	Nitrogen
h	740	Nitrogen
i	970	Atmospheric air

[0051]

[Table 4]

No.	Steel kind	Manufacturing condition	Scale thickness (μm)	FeO ratio (vol%)	Fe ₂ SiO ₄ ratio (vol%)	Scale peeling ratio of rolled material (area%)	MD performance
							Remaining scale area ratio after applying 6% strain (%)
1	A-1	a	1.5	35	0.02	0.6	28
2	A-1	d	4.6	47	0.05	0.8	18
3	A-1	b	1.2	26	0.01	1.9	35
4	A-2	a	1.9	36	0.03	0.8	21
5	A-3	c	2.3	39	0.01	0.6	18
6	A-4	d	5.9	63	0.05	0.5	10
7	A-5	e	6.8	67	0.06	0.2	8
8	A-6	c	3.2	52	0.01	0.6	13
9	A-7	a	1.3	41	0.02	0.5	17
10	A-8	d	4.4	52	0.01	0.8	16
11	A-9	e	6.1	72	0.08	0.6	19
12	A-10	a	2.4	33	0.02	0.9	20
13	A-11	e	7.0	79	0.03	0.8	29
14	A-12	d	6.5	53	0.07	1.1	11
15	A-13	c	2.4	36	0.01	0.8	16
16	A-14	a	1.9	34	0.01	1.2	24
17	A-15	c	2.7	39	0.02	0.9	25
18	A-16	d	4.5	48	0.02	0.7	12
19	A-17	e	5.3	56	0.05	0.5	5
20	A-18	c	3.4	43	0.03	0.6	11

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(continued)

No.	Steel kind	Manufacturing condition	Scale thickness (μm)	FeO ratio (vol%)	Fe ₂ SiO ₄ ratio (vol%)	Scale peeling ratio of rolled material (area%)	MD performance
							Remaining scale area ratio after applying 6% strain (%)
21	A-19	e	5.5	61	0.09	0.7	9
22	A-20	d	4.1	46	0.04	0.8	12
23	A-21	a	1.3	31	0.03	0.9	18
24	A-22	c	1.9	42	0.02	0.4	14
25	A-23	d	3.8	47	0.02	0.5	12
26	A-24	e	5.4	55	0.05	1.1	7

[0052]

[Table 5]

No.	Steel kind	Manufacturing condition	Scale thickness (μm)	FeO ratio (vol%)	Fe ₂ SiO ₄ ratio (vol%)	Scale peeling ratio of rolled material (area%)	MD performance
							Remaining scale area ratio after applying 6% strain (%)
27	B	a	1.1	39	0.02	0.8	16
28	B	c	1.8	44	0.03	1	13
29	B	b	1.5	21	0.02	1.8	41
30	C	c	2.4	42	0.04	0.8	15
31	C	d	3.6	58	0.04	0.5	11
32	D	e	5.5	71	0.05	0.7	22
33	D	g	8.8	82	0.16	0.03	32
34	E	c	2.5	32	0.03	0.9	27
35	E	e	5.6	44	0.04	0.7	19
36	E	f	6.1	25	0.04	1.9	31
37	F	d	3.4	45	0.02	0.9	17
38	F	a	1.5	31	0.01	0.8	24
39	F	e	4.1	54	0.02	0.6	10
40	F	b	1.6	14	0.01	1.9	52
41	G	a	1.5	44	0.01	1	14
42	G	d	3.2	57	0.04	0.5	7
43	G	f	6.0	27	0.05	1.8	35
44	H	a	0.9	31	0.01	0.7	18
45	H	e	4.5	61	0.03	0.6	10
46	H	b	1.8	8	0.02	1.8	56

(continued)

No.	Steel kind	Manufacturing condition	Scale thickness (μm)	FeO ratio (vol%)	Fe_2SiO_4 ratio (vol%)	Scale peeling ratio of rolled material (area%)	MD performance
							Remaining scale area ratio after applying 6% strain (%)
47	H	f	6.7	19	0.08	1.9	43
48	I	d	4.8	68	0.05	0.8	14
49	I	h	0.8	6	0.01	1.8	59
50	A-1	i	7.1	41	0.02	2.9	10
51	B	i	7.5	38	0.01	3.5	11
52	E	i	8.2	45	0.03	5.7	9
53	G	i	7.8	42	0.02	4.2	12
54	I	i	8.5	35	0.01	6.1	4

[0053] Nos. 1, 2, 4-28, 30-32, 34, 35, 37-39, 41, 42, 44, 45, 48 of Tables 4, 5 are examples satisfying the requirements of the present invention, the scale thickness and the composition of the scale are appropriate, and therefore the MD property is excellent.

[0054] On the other hand, in Nos. 3, 29, 33, 36, 40, 43, 46, 47, 49, the MD property deteriorated, because the manufacturing condition did not satisfy the requirements of the present invention.

Nos. 3, 29, 36, 40, 43, 46, 47 are examples cooling was executed by injecting the atmospheric air after hot rolling, the FeO fraction could not be secured because FeO was converted to Fe_3O_4 during cooling, and the MD property deteriorated. No. 33 is an example the winding temperature after hot rolling was high, the scale thickness became thick, the FeO ratio increased excessively, the Fe_2SiO_4 ratio was also high, and therefore the MD property deteriorated. No. 49 is an example the winding temperature after hot rolling was low, the FeO ratio could not be secured, and the MD property deteriorated. Nos. 50-54 are examples the winding temperature after hot rolling was further high, the scale thickness exceeded 7.0 μm , the scale peeling ratio of the rolled material increased, and the rust was generated. More specifically, in Nos. 50-54, it is considered that the scale drops during cooling after hot rolling and at the time of storage and transportation, and the rust is generated.

[0055] Also, the relation between the scale thickness and the scale peeling ratio of the rolled material is shown in Fig. 2. It is known that the scale peeling ratio of the rolled material increases when the scale thickness becomes thick exceeding 7.0 μm .

[0056] The present invention has been described in detail and referring to a specific embodiment, however, it is clear for a person with an ordinary skill in the art that a variety of alterations and modifications can be added without departing from the spirit and scope of the present invention.

The present application is based on the Japanese Patent Application No. 2011-002014 applied on January 7, 2011, and the contents thereof are hereby incorporated by reference.

[Industrial applicability]

[0057] The steel wire material of the present invention is excellent in the mechanical descaling performance after hot rolling (before drawing work), and is therefore useful as a raw material for a tire cord (steel cord, bead wire) for an automobile, hose wire, a saw wire and the like used for cutting a silicon for a semiconductor and the like.

Claims

1. A steel wire material comprising:

C: 0.05-1.2% ("%" means "% by mass", hereinafter the same for chemical components);

Si: 0.01-0.5%;

Mn: 0.1-1.5%;

P: 0.02% or less (not including 0%);
 S: 0.02% or less (not including 0%); and
 N: 0.005% or less (not including 0%); with the remainder being iron and unavoidable impurities, wherein
 a scale with 7.0 μm or less thickness is included,
 FeO ratio inside the scale is 30-80 vol%, and
 Fe_2SiO_4 ratio is less than 0.1 vol%.

2. The steel wire material according to claim 1, further comprising at least one of (1)-(6) described below:

- (1) Cr: 0.3% or less (not including 0%) and/or Ni: 0.3% or less (not including 0%);
- (2) Cu: 0.2% or less (not including 0%);
- (3) At least one element selected from a group consisting of Nb, V, Ti, Hf and Zr by 0.1% or less (not including 0%) in total;
- (4) Al: 0.1% or less (not including 0%);
- (5) B: 0.005% or less (not including 0%); and
- (6) Ca: 0.01% or less (not including 0%) and/or Mg: 0.01% or less (not including 0%).

3. A method for manufacturing a steel wire material comprising the steps of:

hot rolling steel of the chemical composition according to claim 1 or 2;
 thereafter winding up the hot rolled steel at 750-880°C; and
 cooling the wound steel while injecting a gas mixture of oxygen and an inert gas whose oxygen fraction is less than 20 vol% or an inert gas.

4. The method for manufacturing according to claim 3, wherein the inert gas is nitrogen.

FIG. 1

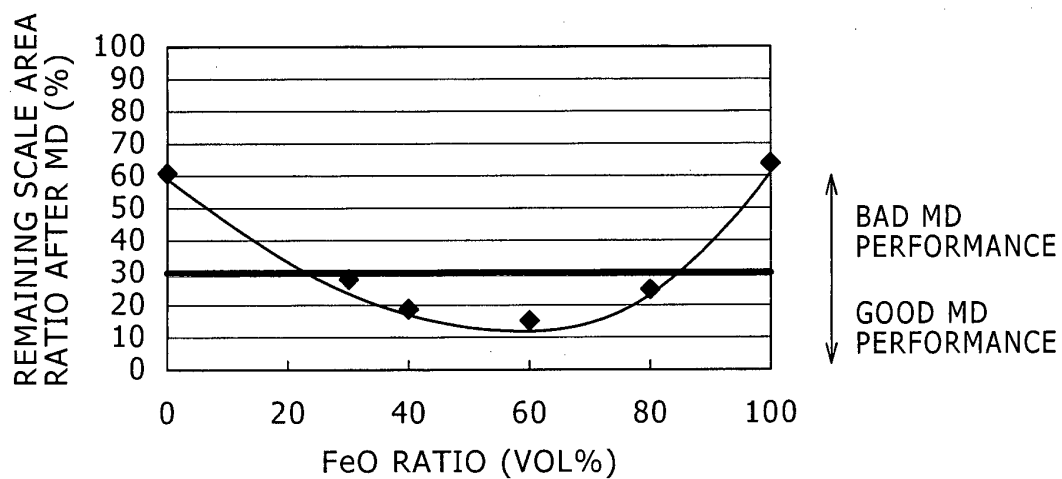
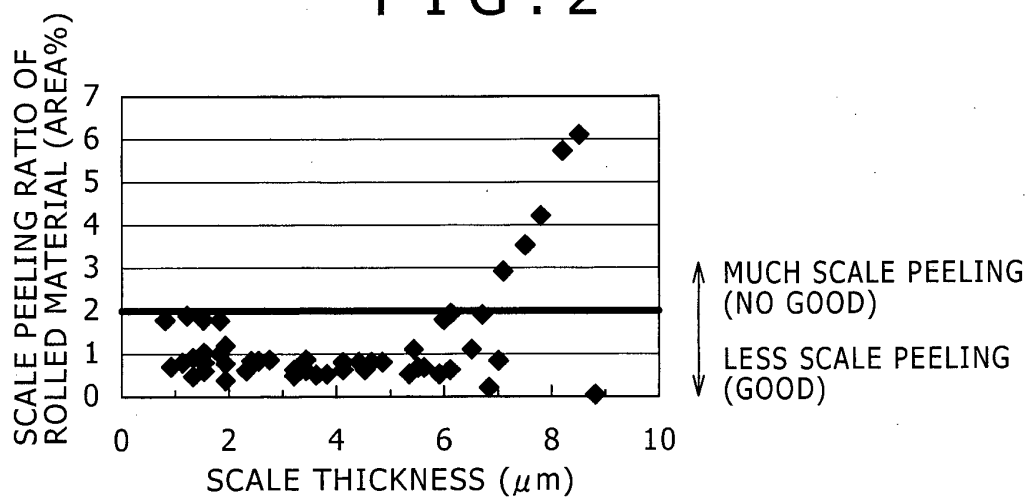


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/050155

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/00 (2006.01) i, C21D9/52 (2006.01) i, C22C38/04 (2006.01) i, C22C38/54 (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)
C22C1/00-49/14, C21D9/52

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012
Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	JP 2008-69376 A (Kobe Steel, Ltd.), 27 March 2008 (27.03.2008), (Family: none)	1-4

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means	
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Date of the actual completion of the international search
16 March, 2012 (16.03.12)

Date of mailing of the international search report
27 March, 2012 (27.03.12)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/050155

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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