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(54) **Wire rod having excellent wire drawability and its production method**

(57) A wire rod, whose tensile strength after wire drawing becomes more or less 3,000 MPa, which does not cause wire breakage even if wire drawing speed is increased, which does not shorten the life time of a dice, and whose wire drawability is improved, contains C: 0.65-0.75%, Si: 0.1-0.5%, Mn: 0.1-0.6%, P: 0.015% or below (not including 0%), S: 0.015% or below (not in-

cluding 0%), N: 0.004% or below (not including 0%), Al: 0.003% or below (not including 0%), O: 0.003% or below (not including 0%), the balance being iron and inevitable impurities, tensile strength (TS) being 960 MPa or below, and reduction of area (RA) being 40% or above.

EP 2 034 036 A2

Description

[0001] The present invention relates to a wire rod (hot rolled wire rod) which becomes a raw material for wire rod products such as steel cords, bead wires.

[0002] Steel cords, bead wires or the like are manufactured usually by wire drawing after descaling (mechanical descaling, acid washing treatment or the like, for example) the wire rod obtained by hot rolling of a billet with approximately 0.7-0.8% carbon content. If the wire rod is broken in wire drawing, productivity is impaired markedly, therefore excellent wire drawability is required for wire rods.

[0003] The present applicant previously proposed several techniques for improving wire drawability of wire rods.

[0004] In JP-A-2004-137597 (Patent Document 1), a technique is disclosed where drawability is improved in wire drawing of the wire rod in an as-hot-rolled state, in addition to by stipulating the composition of the wire rod, by stipulating the average value of the tensile strength, the standard deviation of the tensile strength, the average value of the fracture drawing, and the standard deviation of the fracture drawing, of the wire rod.

[0005] In JP-A-2005-206853 (Patent Document 2), a wire rod is proposed wherein a patenting treatment before or during wire drawing can be omitted and excellent wire drawing is possible in an as-hot-rolled state, in addition to by stipulating the composition of the wire rod, by stipulating the average tensile strength and the average lamellar spacing.

[0006] In JP-A-2006-200039 (Patent Document 3), a wire rod is proposed wherein increase of wire drawing speed, increase of reduction ratio of area, and extension of the life time of a dice are possible, in addition to by stipulating the composition of the wire rod, by optimizing the metal structure (average crystal particle diameter and the maximum crystal particle diameter).

[0007] However, the wire rod actually proposed in an example level in the Patent Documents contained C by more or less 0.8% to secure the tensile strength of 3,500 MPa level by wire drawing. Consequently, tensile strength of most of wire rods exceeded 1,000 MPa, and wire drawing speed could not be increased and remained at 800 m/min at maximum. (Refer to Patent Document 3.)

[0008] On the other hand, in the market, although there is a demand for the wire rods whose tensile strength becomes 3,500 MPa level by wire drawing, a demand of the wire rods whose tensile strength becomes 3,000 MPa level after wire drawing is greater, and at present, the latter wire rods are in circulation as the wire rods for the use of general products. Therefore, the wire rod, whose tensile strength becomes 3,000 MPa level after wire drawing, which does not cause wire breakage even if it is drawn at high speed, and which does not shorten the life time of a dice, is required.

[0009] Under the circumstances the present invention has been developed and its purpose is to provide a wire rod, whose tensile strength after wire drawing becomes more or less 3,000 MPa level, which does not cause wire breakage even if the wire drawing speed is increased, which does not shorten the life time of a dice, and whose wire drawability is improved. Another purpose of the present invention is to provide a method for producing a wire rod excellent in wire drawability.

[0010] The wire rod according to one aspect the present invention addressing the aforementioned problems is the wire rod with the essential points of containing C: 0.65-0.75% (in mass%, hereafter the same with regard to the composition), Si: 0.1-0.5%, Mn: 0.1-0.6%, P: 0.015% or below (not including 0%), S: 0.015% or below (not including 0%), N: 0.004% or below (not including 0%), Al: 0.003% or below (not including 0%), O: 0.003% or below (not including 0%), the balance comprising iron and inevitable impurities, wherein tensile strength (TS) is 960 MPa or below, and reduction of area (RA) is 40% or above.

[0011] The wire rod according to the aspect of the present invention may further contain, as other elements, (1) Cr: 0.5% or below (not including 0%), (2) Cu: 0.5% or below (not including 0%).

[0012] The wire rod according to another aspect of the present invention can be produced by going through a process for heating a billet satisfying the above composition at 1,080 DEG C. or below, a process for hot rolling of the heated billet with the lowest temperature during rolling being made 920 DEG C. or below, a process for finish rolling of the wire rod obtained by the hot rolling at 980 DEG C. or below, a process for winding the wire rod obtained by the finish rolling at 940 DEG C. or below, a process for cooling the wound wire rod from the winding temperature to 800 DEG C. at average cooling rate (CR₁) of 10 DEG C./s or below, a process for cooling consecutively from 800 DEG C. to the temperature range of 640-600 DEG C. at average cooling rate (CR₂) of 30 DEG C./s or above, and a process for heating the wire rod cooled to the temperature range of 640-600 DEG C. at 680 DEG C. or below. In particular, it is recommendable to perform the winding process described above at 880 DEG C. or above.

[0013] In accordance with the aspects of the present invention, by hot rolling of the billet whose composition is stipulated under an appropriate condition and by subsequently cooling under an appropriate condition, the tensile strength of the wire rod can be made 960 MPa or below and the reduction of area can be made 40% or above, accordingly, the wire drawing speed can be made higher than before in wire drawing of the wire rod, and shortening of the life time of the dice can be avoided.

FIG. 1 is a drawing showing the heat pattern in producing the hot rolled wire rod in accordance with the present

invention.

FIG. 2 is a graph showing the relation between tensile strength (TS) and reduction of area (RA).

[0014] The present inventors have made intensive investigations to improve wire drawability of the wire rod whose tensile strength becomes 3,000 MPa level in wire drawing. As a result, it was found out that wire rod drawability could be improved if the tensile strength of the hot rolled wire rod was made 960 MPa or below and the reduction of area was made 40% or above, and that, in order to make such tensile strength and reduction of area coexist, the composition of the hot rolled wire rod should be adjusted appropriately and the hot rolling condition and the cooling condition after hot rolling should be controlled appropriately, and the present invention was accomplished.

[0015] First, the composition of the hot rolled wire rod in accordance with the present invention will be described. The hot rolled wire rod in accordance with the present invention contains C: 0.65-0.75%, Si: 0.1-0.5%, Mn: 0.1-0.6%, P: 0.015% or less (not including 0%), S: 0.015% or below (not including 0%), N: 0.004% or below (not including 0%), Al: 0.003% or less (not including 0%), O: 0.003% or less (not including 0%).

[0016] C is the element necessary for securing the strength of wire rod products. However, the purpose of the present invention is to provide the hot rolled wire rod which becomes the raw material of, among wire rod products, not the high strength product whose tensile strength is 3,500 MPa level, but the general product whose tensile strength is 3,000 MPa level. Although C of the hot rolled wire rod is required to be made as much as possible in producing the high strength product, because production of the general product is envisaged in the present invention, C of the hot rolled wire rod is comparatively less than the case of production of high strength product, and is to be in the range of 0.65-0.75%.

[0017] However, if C is below 0.65%, tensile strength of wire rod products cannot be secured, therefore, C is made 0.65% or above, preferably 0.68% or above, or more preferably 0.7% or above. On the other hand, if C is contained excessively, wire drawability is deteriorated because tensile strength becomes too high, ductility is deteriorated, and reduction of area becomes little. Therefore, C is made 0.75% or below, preferably 0.74% or below, or more preferably 0.73% or below.

[0018] Si is the element acting as a deoxidizing agent. If Si is below 0.1%, deoxidization is not enough, troubles in steel making become liable to occur, and wire drawability of wire rods is deteriorated as solid solution oxygen increases. Therefore, Si is required to be contained by 0.1% or above, preferably 0.13% or above, or more preferably 0.15% or above. On the other hand, Si increases the strength of the hot rolled wire rod by solid solution strengthening and has an action to promote decarburization. However, if Si becomes excessive, the tensile strength of the hot rolled wire rod becomes too high and wire breakage occurs in wire rod drawing. Therefore, Si is made 0.5% or below, preferably 0.48% or below, or more preferably 0.4% or below.

[0019] Not only acting as a deoxidizing agent, Mn also has an action to detoxify S by fixing S, a harmful element, as MnS. Also, Mn has an action to stabilize carbide in steel. However, if Mn is below 0.1%, detoxification of S becomes insufficient and drawability of wire rods is deteriorated. Further, crack possibly occurs in hot rolling. Therefore, Mn is required to be contained by 0.1% or above, preferably 0.13% or above, or more preferably 0.2% or above. However, if Mn becomes excessive, the tensile strength of the hot rolled wire rod becomes too high and wire breakage occurs in wire drawing. Also, segregation and super cooled structure are liable to occur which become the cause of wire breakage. Therefore, Mn is made 0.6% or below, preferably 0.58% or below, or more preferably 0.55% or below.

[0020] P is an inevitable impurity element, and if it is contained in excess, it deteriorates toughness and ductility of the hot rolled wire rod which becomes the cause of wire breakage in wire drawing. Therefore, P is made 0.015% or below, preferably 0.014% or below, more preferably 0.013% or below, further more preferably 0.010% or below.

[0021] S is an inevitable impurity element, is trapped by Mn and is fixed as MnS. However, if S becomes excessive, because MnS amount increases and the size becomes large, ductility of the hot rolled wire rod deteriorates which becomes the cause of wire breakage in wire drawing. Therefore, S is made 0.015% or below, preferably 0.013% or below, more preferably 0.01% or below, further more preferably 0.007% or below.

[0022] Although N is an inevitable impurity element, it is an element acting for improving tensile strength of the hot rolled wire rod by age hardening. However, if it is contained in excess, it deteriorates ductility of the hot rolled wire rod which becomes the cause of wire breakage in wire drawing. Therefore, N is made 0.004% or below, preferably 0.0035% or below, more preferably 0.003% or below, further more preferably 0.0025% or below, especially more preferably 0.002% or below.

[0023] Al is an element not only acting as a deoxidizing agent, but also acting to form AlN by combining with N, and to refine the structure and improve toughness of the hot rolled wire rod. To make these actions be exerted, it is preferable to contain 0.0001% or above, more preferably 0.0002% or above, further more preferably 0.0003% or above. However, if excessively contained, hard oxide (Al_2O_3 or the like, for example) is formed in the hot rolled wire rod which becomes the cause of wire breakage in wire drawing. Therefore, Al is made 0.003% or below, preferably 0.002% or below, more preferably 0.001% or below.

[0024] O (oxygen) is an inevitable impurity element, and if O becomes excessive, coarse oxide-based inclusions are formed in the hot rolled wire rod which becomes the cause of wire breakage in wire drawing. Therefore, O is made

0.003% or below, preferably 0.0025% or below, more preferably 0.002% or below, further more preferably 0.0015% or below, most preferably 0.001% or below.

[0025] The hot rolled wire rod in accordance with the present invention contains the elements described above and the balance is iron and inevitable impurities.

[0026] As other elements, the hot rolled wire rod in accordance with the present invention may contain (1) high strengthening elements such as Cr, and (2) anti-corrosion property improve elements such as Cu.

[0027] (1) Cr is an element contributing to improving hardenability and increasing the strength of wire rod products. To exert these actions effectively, it is preferable to contain Cr by 0.01% or above, more preferably 0.02% or above, further more preferably 0.1% or above. However, if Cr is contained in excess, the tensile strength of the hot rolled wire rod becomes too high, super cooled structure is liable to be formed, and wire drawability deteriorates. Therefore, it is preferable to make Cr 0.5% or below, more preferably 0.45% or below, further more preferably 0.4% or below.

[0028] (2) Cu is an element contributing to not only inhibiting surface layer decarburization but also to improving anti-corrosion property of wire rod products. To exert such actions effectively, it is preferable to contain Cu by 0.01% or above, more preferably 0.05% or above, further more preferably 0.1% or above. However, if Cu is contained in excess, crack is generated in hot rolling, super cooled structure is formed, and wire drawability deteriorates. Therefore, it is preferable to make Cu 0.5% or below, more preferably 0.45% or below, further more preferably 0.4% or below.

[0029] In the hot rolled wire rod in accordance with the present invention, it is important that the chemical composition described above is contained, and, in addition, that tensile strength (TS) is 960 MPa or below and reduction of area (RA) is 40% or above. If tensile strength (TS) exceeds 960 MPa, working heat quantity generated in wire drawing increases, seizure occurs during wire drawing, thereby the life time of a dice is shortened and wire breakage occurs. On the other hand, if reduction of area (RA) is below 40%, cuppy break becomes liable to occur during wire drawing.

[0030] The tensile strength and the reduction of area of the hot rolled wire rod in accordance with the present invention are obtained by cutting test pieces for tensile test from the wire rod obtained by hot rolling, measuring tensile strength (TS) and reduction of area (RA) on a plurality of test pieces (number of the test pieces is 80, for example) according to ordinary methods, and averaging them. The strain rate in testing can be made $1.0 \times 10^{-3} \text{ s}^{-1}$ to $3.5 \times 10^{-3} \text{ s}^{-1}$.

[0031] The hot rolled wire rod in accordance with the present invention described above can be produced by appropriately controlling the hot rolling condition and the cooling condition after hot rolling. In other words, for the hot rolled wire rod in accordance with the present invention, the hot rolling condition and the cooling condition after hot rolling are to be controlled to follow the heat pattern exhibited in FIG. 1, and if

- (a) a process for heating a billet satisfying the above composition at 1,080 DEG C. or below,
 - (b) a process for hot rolling of the heated billet with the lowest temperature during rolling being made 920 DEG C. or below,
 - (c) a process for finish rolling of the wire rod obtained by the hot rolling at 980 DEG C. or below,
 - (d) a process for winding the wire rod obtained by the finish rolling at 940 DEG C. or below,
 - (e) a process for cooling the wound wire rod from the winding temperature to 800 DEG C. at average cooling rate (CR_1) of 10 DEG C./s or below,
 - (f) a process for cooling consecutively from 800 DEG C. to the temperature range of 640-600 DEG C. at average cooling rate (CR_2) of 30 DEG C./s or above, and
 - (g) a process for heating the wire rod cooled to the temperature range of 640-600 DEG C. at 680 DEG C. or below,
- are performed in this order, the hot rolled wire rod in accordance with the present invention can be produced. The reasons such producing conditions were stipulated are as follows.

[0032] (a) If the heating temperature of the billet exceeds 1,080 DEG C., the tensile strength of the hot rolled wire rod increases, the reduction of area decreases, and wire drawability deteriorates. Therefore, in the present invention, the heating temperature of the billet is made 1,080 DEG C. or below. Usually, the lower limit of the heating temperature of the billet is approximately 1,000 DEG C. The preferable upper limit of the heating temperature of the billet is 1,060 DEG C. and the preferable lower limit is 1,020 DEG C.

[0033] (b) In hot rolling of the billet heated to the heating temperature described above, if the lowest temperature during rolling exceeds 920 DEG C., the tensile strength of the hot rolled wire rod increases, the reduction of area decreases, and wire drawability deteriorates. Therefore, according to the present invention, hot rolling is performed with the lowest temperature during rolling being made 920 DEG C. or below. Usually, the lower limit of the lowest temperature during hot rolling is approximately 820 DEG C. The preferable upper limit of the lowest temperature during hot rolling is 900 DEG C., more preferable upper limit is 880 DEG C., preferable lower limit is 840 DEG C., more preferable lower limit is 860 DEG C.

[0034] (c) If the finish rolling temperature of the wire rod obtained by hot rolling exceeds 980 DEG C., the tensile strength of the hot rolled wire rod increases, or the reduction of area decreases, and wire drawability deteriorates. Therefore, in the present invention, finish rolling is performed with the finish rolling temperature being made 980 DEG

C. or below. Usually, the lower limit of the finish rolling temperature is approximately 820 DEG C. Preferable upper limit of the finish rolling temperature is 960 DEG C., more preferable upper limit is 940 DEG C., preferable lower limit is 840 DEG C., more preferable lower limit is 860 DEG C., specially preferable lower limit is 900 DEG C.

[0035] (d) After performing finish rolling, the wire rod is wound in ring-shape onto a transport device such as a conveyor, but if winding temperature exceeds 940 DEG C., the tensile strength of the hot rolled wire rod increases, the reduction of area decreases, and wire drawability deteriorates. Therefore, in the present invention, winding is performed with the winding temperature being made 940 DEG C. or below. Preferable upper limit of the winding temperature is 920 DEG C., and more preferable upper limit is 910 DEG C. However, if the winding temperature is made too low, mechanical descaling property (MD property) deteriorates, therefore, the winding temperature is preferably made 880 DEG C. or above. More preferable lower limit of the winding temperature is 890 DEG C., further more preferable lower limit is 900 DEG C. Also, the winding temperature can be adjusted by controlling the condition of water cooling performed after finish rolling.

[0036] In (e) and (f), it is important that two-step cooling is performed with the boundary of 800 DEG C. from the winding temperature to a temperature T_1 in the temperature range of 640-600 DEG C., more specifically, slow cooling in the range from the winding temperature to 800 DEG C., and quick cooling in the range from 800 DEG C. to the temperature T_1 . The mechanism of improvement of wire drawability by decrease of the tensile strength and increase of the reduction of area of the hot rolled wire rod by combination of slow cooling and quick cooling has not been clarified, but can be presumed as below.

[0037] The present inventors consider that ferrite is formed by slow cooling in the range from the winding temperature to 800 DEG C., and metal structure is made finer by quick cooling in the range from 800 DEG C. to the temperature T_1 , thereby the tensile strength of hot rolled wire rod decreases, the reduction of area increases, and wire drawability can be improved.

[0038] (e) If average cooling rate (CR_1) from the winding temperature to 800 DEG C. exceeds 10 DEG C./s, the tensile strength of the hot rolled wire rod increases and wire drawability deteriorates. Therefore, in the present invention, CR_1 is made 10 DEG C./s or below, preferably 9 DEG C./s or below, more preferably 8 DEG C./s or below. Lower limit of the average cooling rate (CR_1) is not limited particularly, but is, for example, 1 DEG C./s, preferably 2 DEG C./s.

[0039] (f) If average cooling rate (CR_2) from 800 DEG C. to the temperature T_1 is below 30 DEG C./s, metal structure does not become finer, therefore, the reduction of area of the hot rolled wire rod decreases and wire drawability deteriorates. Therefore, in the present invention, the average cooling rate (CR_2) is made 30 DEG C./s or above, preferably 33 DEG C./s or above, more preferably 35 DEG C./s or above. Upper limit of the average cooling rate (CR_2) is not limited particularly, but is, for example, 65 DEG C./s, preferably 60 DEG C./s.

[0040] Further, if the temperature T_1 exceeds 640 DEG C., the reduction of area of the hot rolled wire rod decreases, and if the temperature T_1 is below 600 DEG C., the tensile strength of the hot rolled wire rod increases, and wire drawability of the hot rolled wire rod deteriorates. Therefore, in the present invention, the ultimate temperature T_1 in cooling from 800 DEG C. is made 640-600 DEG C., preferably 638 DEG C. or below, more preferably 635 DEG C. or below. Also, it is preferably 605 DEG C. or above, more preferably 610 DEG C. or above.

[0041] (g) If heated after cooling to the temperature T_1 , the tensile strength of the hot rolled wire rod can be decreased, however, if heated to above 680 DEG C., the reduction of area decreases and wire drawability deteriorates. Therefore, in the present invention, after cooled to the temperature T_1 , the wire rod is heated to a temperature T_2 of 680 DEG C. or below, exceeding the temperature T_1 . The temperature T_2 is preferably 675 DEG C. or below, more preferably 670 DEG C. or below. Further, if kept as it is at the temperature T_1 or consecutively cooled to the room temperature after cooled to the temperature T_1 , the tensile strength of the hot rolled wire rod becomes too high and wire drawability deteriorates.

[0042] The hot rolled wire rod in accordance with the present invention thus obtained becomes excellent in wire drawability because the tensile strength becomes 960 MPa or below and the reduction of area becomes 40% or above. By performing wire drawing this hot rolled wire rod after descaling according to an ordinary method (mechanical descaling, acid washing treatment, or the like, for example), a wire rod with tensile strength level of 3,000 MPa level can be obtained.

[0043] Although the present invention will be described below in further detail by referring to the examples, the present invention is by no means to be limited by the examples below and can be implemented with appropriate modifications added 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.

[0044] The billets (steel kinds of A1-A32) of the composition exhibited in TABLE 1 below (balance is iron and inevitable impurities) were subjected to heating, hot rolling, winding and cooling according to the heat pattern exhibited in FIG. 1, and the hot rolled wire rods of 5.5 mm diameter were produced. TABLE 2 and TABLE 3 below exhibit; heating temperature, the lowest temperature during rolling, finish rolling temperature, winding temperature, average cooling rate from winding temperature to 800 DEG C. (CR_1), average cooling rate from 800 DEG C. to a temperature T_1 in the temperature range of 640-600 DEG C. (CR_2), temperature T_2 when heated from the temperature T_1 , respectively.

[0045] The tensile property was evaluated on the hot rolled wire rods obtained. The evaluation of the tensile property

was performed by preparing 8 test pieces for tensile test by dividing one ring (the length of one ring is approximately 4 m) of the hot rolled wire rod into 8 pieces, and by performing tensile tests using the test pieces for 10 rings (80 pieces in total). The strain rate in the tensile test was set at $1.0 \times 10^{-3} \text{ s}^{-1}$ to $3.5 \times 10^{-3} \text{ s}^{-1}$ and tensile strength (TS: MPa) and reduction of area (RA: %) were measured. Average of all test pieces are referred to as tensile strength (TS) and reduction of area (RA) respectively, and the results are exhibited in TABLE 4 and TABLE 5 below.

[0046] Also, the relation between tensile strength (TS) and reduction of area (RA) is exhibited in FIG. 2. ○ in FIG. 2 exhibits the results of Nos.1-5, No.8, Nos.10-14, No.21, Nos.26-33, Nos.38-40, No.46, No.47, and Nos.53-55. × in FIG. 2 exhibits the results of No.6, No.7, No.9, No.15, Nos.22-25, Nos.34-37, Nos.41-45, Nos.49-52, and Nos.56-60.

[0047] Then, wire drawability of the hot rolled wire rods obtained was evaluated. After descaling the 5.5 mm diameter hot rolled wire rod, dry drawing was performed so that the final wire diameter becomes 0.9 mm using a continuous drawing machine, and wire drawability was evaluated based on whether wire breakage had occurred or not in wire drawing and the life time of the dice.

[0048] The wire drawing conditions were as described below, and 2 tons for each hot rolled wire rod were used for the test. Whether or not wire breakage had occurred was visually confirmed. The life time of the dice was evaluated according to the criteria described below by visually observing the dice after drawing. The results are exhibited in TABLE 4 and TABLE 5 below.

[Condition of Drawing]

[0049]

Descaling:	Mechanical descaling (MD)
Number of dice:	18 pieces
Final drawing speed:	1,000 m/min (1,100 m/min only when wire breakage did not occur at 1,000 m/min)
Intermediate heat treatment:	None

[Evaluation Criteria of Life Time of Dice]

[0050]

○ (passed): The case wherein replacement of the dice for breakage and wear of the dice was not necessary.

△ (Failed): The case wherein although breakage of the dice did not occur, replacement of the dice became necessary after wire drawing because of the wear of the dice.

× (Failed): The case wherein the dice was broken during wire drawing.

- (Failed): The case wherein the life time of the dice could not be evaluated because of wire breakage during wire drawing.

[0051] In the present invention, in the case wherein wire breakage did not occur and the life time of the dice passed in the evaluation when the final drawing speed was made 1,000 m/min, wire drawability was judged to be excellent, and in the case wherein wire breakage did not occur and the life time of the dice passed in the evaluation when the final drawing speed was made 1,100 m/min, wire drawability was judged to be particularly excellent.

[0052] Based on FIG. 2, following analysis is possible. In the example wherein the conditions stipulated in the present invention were satisfied (○ mark in FIG. 2), wire drawability could be improved. On the other hand, in the example wherein the conditions stipulated in the present invention were not satisfied (× mark in FIG. 2), if the tensile strength (TS) of the hot rolled wire rod had increased to exceed 960 MPa, seizure occurred in wire drawing and wire breakage occurred. Also, the life time of the dice was shortened. Further, if the reduction of area (RA) of the hot rolled wire rod had been below 40%, wire breakage occurred during wire drawing.

[0053] From TABLE 1-TABLE 5 below, following analysis is possible. In No.6 and No.56, because the cooling speed from winding temperature to 800 DEG C. had not been appropriately controlled, tensile strength increased and wire drawability could not be improved. In No.7, because the cooling speed from 800 DEG C. to the temperature T_1 had not been appropriately controlled, the reduction of area decreased and wire drawability could not be improved. In No.9, because the cooling speed from 800 DEG C. to the temperature T_1 had not been appropriately controlled, the reduction of area decreased. Further, because cooled to room temperature after maintained at the constant temperature for 15 seconds after cooled to 610 DEG C. (temperature T_1) after finish rolling, the tensile strength increased. Therefore, wire drawability could not be improved.

[0054] In Nos.15-20, No.48, No.49, No.52, No.59 and No.60, because the composition of the hot rolled wire rod had

been deviated from the range the present invention had stipulated, wire drawability could not be improved. Particularly in No.59 and No.60 which are the examples wherein C had been contained by 0.80% or above, even if the cooling speed CR_1 and the cooling speed CR_2 had been appropriately controlled, the tensile strength increased, the reduction of area decreased, and wire drawability could not be improved.

[0055] In No.50, because Cu had been contained in excess, the tensile strength increased, and wire drawability could not be improved. In No.51, because Cr had been contained in excess, the tensile strength increased, the reduction of area decreased, and wire drawability could not be improved.

[0056] In No.22 and No.42, because the wire rod had been consecutively cooled to the room temperature after cooling from 800 DEG C. to the temperature T_1 , the tensile strength increased, and wire drawability could not be improved. In No.23 and No.43, because the temperature T_1 had been too low, the tensile strength increased, and wire drawability could not be improved. In No.25 and No.44, because the temperature T_1 had been too high, the reduction of area decreased, and wire drawability could not be improved. In No.24 and No.45, because the heating temperature T_2 had been too high, the reduction of area decreased, and wire drawability could not be improved.

[0057] In No.34, because 2 stage cooling had not been adopted for the range from the winding temperature to the temperature T_1 but had been continually cooled, the tensile strength increased, the reduction of area decreased, and wire drawability could not be improved. In No.35, the heating temperature had been too high, In No.36, the lowest rolling temperature had been too high, and in No.37, the finish rolling temperature had been too high, therefore the tensile strength increased, the reduction of area decreased, and wire drawability could not be improved in all these examples.

[0058] In No.39 and No.40, which are examples for reference, because the winding temperature had been slightly low, MD property deteriorated a little. In No.41, because the winding temperature had been too high, the tensile strength increased, and wire drawability could not be improved.

[0059] In No.57, because the cooling speed from 800 DEG C. to the temperature T_1 had not been appropriately controlled, the reduction of area decreased, and wire drawability could not be improved. In No.58, because the cooling speed from 800 DEG C. to the temperature T_1 had not been appropriately controlled, the reduction of area decreased. Also, because the temperature T_1 had been too low, the tensile strength increased. Therefore, wire drawability could not be improved.

[0060]

[TABLE 1]

Steel kind	Composition (mass%)									
	C	Si	Mn	P	S	Cu	Cr	Al	N	O
A1	0.65	0.47	0.58	0.007	0.007	0.42	0.45	0.0004	0.0034	0.0014
A2	0.70	0.17	0.57	0.006	0.003	-	-	0.0010	0.0038	0.0011
A3	0.71	0.10	0.46	0.002	0.010	0.10	0.28	0.0005	0.0025	0.0011
A4	0.71	0.30	0.36	0.011	0.008	-	0.33	0.0006	0.0019	0.0015
A5	0.71	0.22	0.49	0.008	0.003	-	-	0.0003	0.0026	0.0012
A6	0.71	0.14	0.51	0.011	0.007	-	-	0.0010	0.0035	0.0014
A7	0.71	0.28	0.47	0.004	0.010	-	-	0.0007	0.0039	0.0012
A8	0.71	0.14	0.50	0.014	0.013	-	-	0.0008	0.0019	0.0012
A9	0.71	0.83	0.50	0.005	0.004	-	-	0.0008	0.0040	0.0011
A10	0.71	0.22	0.02	0.005	0.012	-	-	0.0005	0.0039	0.0009
A11	0.71	0.23	0.48	0.020	0.005	-	-	0.0008	0.0023	0.0009
A12	0.71	0.17	0.46	0.014	0.018	-	-	0.0003	0.0033	0.0014
A13	0.71	0.25	0.48	0.008	0.009	-	-	0.0332	0.0030	0.0008
A14	0.71	0.21	0.50	0.004	0.010	-	-	0.0006	0.0025	0.0040
A15	0.72	0.20	0.48	0.014	0.011	0.01	-	0.0004	0.0016	0.0014
A16	0.72	0.16	0.55	0.006	0.007	-	0.02	0.0007	0.0020	0.0014
A17	0.72	0.29	0.48	0.009	0.004	-	-	0.0004	0.0030	0.0008
A18	0.72	0.32	0.27	0.015	0.004	-	-	0.0008	0.0027	0.0013

EP 2 034 036 A2

(continued)

Steel kind	Composition (mass%)									
	C	Si	Mn	P	S	Cu	Cr	Al	N	O
A19	0.72	0.22	0.47	0.011	0.003	-	-	0.0006	0.0027	0.0015
A20	0.72	0.22	0.45	0.008	0.004	-	-	0.0004	0.0025	0.0010
A21	0.72	0.16	0.55	0.004	0.009	0.01	0.01	0.0007	0.0015	0.0010
A22	0.72	0.10	0.52	0.014	0.003	-	-	0.0009	0.0018	0.0009
A23	0.72	0.03	0.46	0.005	0.007	-	-	0.0247	0.0016	0.0010
A24	0.72	0.21	0.77	0.004	0.006	-	-	0.0002	0.0037	0.0010
A25	0.72	0.25	0.47	0.010	0.007	0.62	-	0.0004	0.0015	0.0014
A26	0.72	0.23	0.54	0.012	0.010	-	0.70	0.0005	0.0038	0.0010
A27	0.72	0.20	0.54	0.012	0.009	-	-	0.0003	0.0051	0.0012
A28	0.74	0.14	0.54	0.007	0.010	-	-	0.0005	0.0020	0.0014
A29	0.74	0.19	0.14	0.004	0.003	-	-	0.0002	0.0015	0.0015
A30	0.75	0.24	0.22	0.013	0.008	0.15	0.20	0.0004	0.0032	0.0012
A31	0.80	0.27	0.55	0.009	0.006	-	-	0.0007	0.0036	0.0013
A32	0.83	0.23	0.45	0.012	0.010	-	-	0.0009	0.0032	0.0012

[0061]

[TABLE 2]

No.	Steel kind	Heating temp. (DEG C.)	Lowest rolling temp. (DEG C.)	Finish rolling temp. (DEG C.)	Winding temp. (DEG C.)	Cooling rate		Temp.		Remarks
						CR ₁ (DEG C./s)	CR ₂ (DEG C./s)	T ₁ (DEG C.)	T ₂ (DEG C.)	
1	A1	1038	898	947	920	4	48	624	680	
2	A2	1059	879	933	909	4	48	600	653	
3	A3	1055	889	944	904	4	43	614	652	
4	A4	1055	900	950	937	5	43	630	671	
5	A5	1056	880	931	891	4	58	610	627	
6	A5	1049	873	923	904	17	39	602	630	
7	A5	1043	891	946	900	5	14	638	641	
8	A5	1036	898	940	906	4	55	614	668	
9	A5	1055	878	931	902	7	24	610	-	Maintained at constant temp.
10	A6	1043	881	935	899	3	35	637	649	
11	A6	1040	874	930	900	7	41	627	655	
12	A6	1030	870	922	900	6	43	625	662	
13	A7	1047	878	933	924	3	32	626	648	
14	A8	1052	875	929	901	3	43	611	651	
15	A9	1048	899	942	894	6	36	634	655	

EP 2 034 036 A2

(continued)

No.	Steel kind	Heating temp. (DEG C.)	Lowest rolling temp. (DEG C.)	Finish rolling temp. (DEG C.)	Winding temp. (DEG C.)	Cooling rate		Temp.		Remarks
						CR ₁ (DEG C./s)	CR ₂ (DEG C./s)	T ₁ (DEG C.)	T ₂ (DEG C.)	
16	A10	1048	886	939	909	8	47	632	664	
17	A11	1033	896	946	908	4	35	618	624	
18	A12	1055	891	942	910	7	34	625	634	
19	A13	1037	881	936	892	7	48	621	660	
20	A14	1031	894	947	890	8	49	613	659	
21	A15	1050	885	936	903	6	43	613	652	
22	A15	1055	893	946	896	7	31	627	-	Continuous cooling
23	A15	1046	876	928	895	4	32	588	605	
24	A15	1055	890	942	903	8	33	639	684	
25	A15	1046	892	944	892	3	34	655	678	
26	A16	1057	876	928	895	4	37	623	670	
27	A16	1055	870	924	901	3	42	627	668	
28	A16	1054	871	924	903	4	53	612	660	
29	A17	1041	871	922	897	6	43	632	660	
30	A17	1040	876	926	899	4	37	635	662	

[0062]

[TABLE 3]

No.	Steel kind	Heating temp. (DEG C.)	Lowest rolling temp. (DEG C.)	Finish rolling temp. (DEG C.)	Winding temp. (DEG C.)	Cooling rate		Temp.		Remarks
						CR ₁ (DEG C./s)	CR ₂ (DEG C./s)	T ₁ (DEG C.)	T ₂ (DEG C.)	
31	A17	1035	870	920	902	3	31	638	657	
32	A18	1042	900	937	893	7	32	640	671	
33	A19	1036	873	924	907	9	38	634	665	
34	A19	1045	882	939	907	23	23	617	639	One step cooling
35	A19	1091	898	947	891	5	50	630	666	
36	A19	1059	925	950	905	7	49	637	638	
37	A19	1057	900	988	910	4	48	625	636	
38	A20	1032	889	942	909	6	45	638	662	
39	A20	1041	896	946	872	3	31	636	670	MD property slightly bad

EP 2 034 036 A2

(continued)

	No.	Steel kind	Heating temp. (DEG C.)	Lowest rolling temp. (DEG C.)	Finish rolling temp. (DEG C.)	Winding temp. (DEG C.)	Cooling rate		Temp.		Remarks
							CR ₁ (DEG C./s)	CR ₂ (DEG C./s)	T ₁ (DEG C.)	T ₂ (DEG C.)	
5	40	A20	1057	888	930	843	3	30	623	669	MD property slightly bad
10	41	A20	1057	892	950	945	7	42	615	635	
	42	A20	1045	895	945	893	5	32	630	-	Continuous cooling
15	43	A20	1058	871	923	898	6	39	588	614	
	44	A20	1031	871	923	897	7	50	647	661	
	45	A20	1043	884	936	905	6	32	638	685	
20	46	A21	1052	898	948	900	6	49	620	663	
	47	A22	1052	891	941	907	10	30	631	671	
	48	A23	1039	891	943	901	7	37	615	621	
	49	A24	1052	881	935	893	4	48	616	626	
25	50	A25	1049	870	925	904	6	48	618	624	
	51	A26	1044	873	925	903	4	31	613	652	
	52	A27	1033	893	947	891	6	42	631	634	
30	53	A28	1045	895	946	894	3	46	622	670	
	54	A29	1050	898	950	894	3	42	636	662	
	55	A30	1040	897	949	901	4	30	636	678	
	56	A30	1045	889	942	910	15	44	605	646	
35	57	A30	1056	883	934	905	8	25	637	669	
	58	A30	1050	887	941	894	8	26	591	608	
	59	A31	1049	899	950	908	6	50	639	658	
40	60	A32	1031	890	944	899	8	44	625	636	

[0063]

[TABLE 4]

	No.	Tensile strength	Reduction of area	Wire drawing			
				1,000m/s		1,100m/s	
				Wire breakage	Life of dice	Wire breakage	Life of dice
45	1	953	49	No	○	No	○
	2	952	47	No	○	No	○
	3	957	45	No	○	No	○
	4	941	43	No	○	No	○
50	5	951	44	No	○	No	○
55	6	967	42	No	×	Yes	-

EP 2 034 036 A2

(continued)

5	No.	Tensile strength	Reduction of area	Wire drawing			
		TS (MPa)	RA (%)	1,000m/s		1,100m/s	
				Wire breakage	Life of dice	Wire breakage	Life of dice
	7	957	38	Yes	-	-	-
	8	937	40	No	○	No	○
10	9	977	37	Yes	-	-	
	10	951	44	No	○	No	○
	11	945	42	No	○	No	○
	12	940	41	No	○	No	○
15	13	950	44	No	○	No	○
	14	949	44	No	○	No	○
	15	980	42	Yes	-	-	-
20	16	924	43	Yes	-	-	-
	17	949	44	Yes	-	-	-
	18	944	44	Yes	-	-	-
	19	950	44	Yes	-	-	-
25	20	952	44	Yes	-	-	-
	21	954	43	No	○	No	○
	22	974	42	No	×	Yes	-
30	23	991	44	Yes	-	-	-
	24	940	37	Yes	-	-	-
	25	938	33	Yes	-	-	-
	26	945	42	No	○	No	○
35	27	945	44	No	○	No	○
	28	940	42	No	○	No	○
	29	951	43	No	○	No	○
40	30	949	41	No	○	No	○

[0064]

[TABLE 5]

45	No.	Tensile strength	Reduction of area	Wire drawing			
		TS (MPa)	RA (%)	1,000m/s		1,100m/s	
				Wire breakage	Life of dice	Wire breakage	Life of dice
50	31	946	41	No	○	No	○
	32	928	44	No	○	No	○
	33	952	43	No	○	No	○
55	34	980	37	Yes	-	-	-
	35	1008	35	Yes	-	-	-
	36	1012	36	Yes	-	-	-

EP 2 034 036 A2

(continued)

5	No.	Tensile strength	Reduction of area	Wire drawing			
		TS (MPa)	RA (%)	1,000m/s		1,100m/s	
				Wire breakage	Life of dice	Wire breakage	Life of dice
	37	1020	37	Yes	-	-	-
	38	954	43	No	○	No	○
10	39	942	45	No	○	No	△
	40	938	47	No	○	No	△
	41	989	42	Yes	-	-	-
	42	997	40	Yes	-	-	-
15	43	1021	42	Yes	-	-	-
	44	952	37	Yes	-	-	-
	45	935	34	Yes	-	-	-
20	46	953	42	No	○	No	○
	47	957	43	No	○	No	○
	48	949	44	Yes	-	-	-
	49	1011	40	Yes	-	-	-
25	50	997	40	Yes	-	-	-
	51	1119	33	Yes	-	-	-
	52	1010	42	Yes	-	-	-
30	53	956	41	No	○	No	○
	54	948	46	No	○	No	○
	55	960	42	No	○	No	○
	56	1012	42	Yes	-	-	-
35	57	957	34	Yes	-	-	-
	58	1028	38	Yes	-	-	-
	59	1059	37	Yes	-	-	-
40	60	1071	36	Yes	-	-	-

Claims

1. A wire rod excellent in wire drawability containing,
C: 0.65-0.75% (in mass%, hereafter the same with regard to the composition),
Si: 0.1-0.5%,
Mn: 0.1-0.6%,
P: 0.015% or below (not including 0%),
S: 0.015% or below (not including 0%),
N: 0.004% or below (not including 0%),
Al: 0.003% or below (not including 0%),
O: 0.003% or below (not including 0%),
the balance comprising iron and inevitable impurities, wherein tensile strength (TS) is 960 MPa or below, and reduction of area (RA) is 40% or above.
2. The wire rod as set forth in Claim 1, further containing, as other elements,
Cr: 0.5% or below (not including 0%).

EP 2 034 036 A2

3. The wire rod as set forth in Claim 1 or Claim 2, further containing, as other elements, Cu: 0.5% or below (not including 0%).

4. A method for producing a wire rod excellent in wire drawability comprising
a process for heating a billet satisfying the composition as set forth in either of Claims 1 to 3 at 1,080 DEG C. or below,
a process for hot rolling of the heated billet with the lowest temperature during rolling being made 920 DEG C. or below,
a process for finish rolling of the wire rod obtained by the hot rolling at 980 DEG C. or below,
a process for winding the wire rod obtained by the finish rolling at 940 DEG C. or below,
a process for cooling the wound wire rod from the winding temperature to 800 DEG C. at average cooling rate (CR₁) of 10 DEG C./s or below,
a process for cooling consecutively from 800 DEG C. to the temperature range of 640-600 DEG C. at average cooling rate (CR₂) of 30 DEG C./s or above, and
a process for heating the wire rod cooled to the temperature range of 640-600 DEG C. at 680 DEG C. or below.

5. The method of producing as set forth in Claim 4 wherein the winding process is performed at 880 DEG C. or above.

FIG. 1

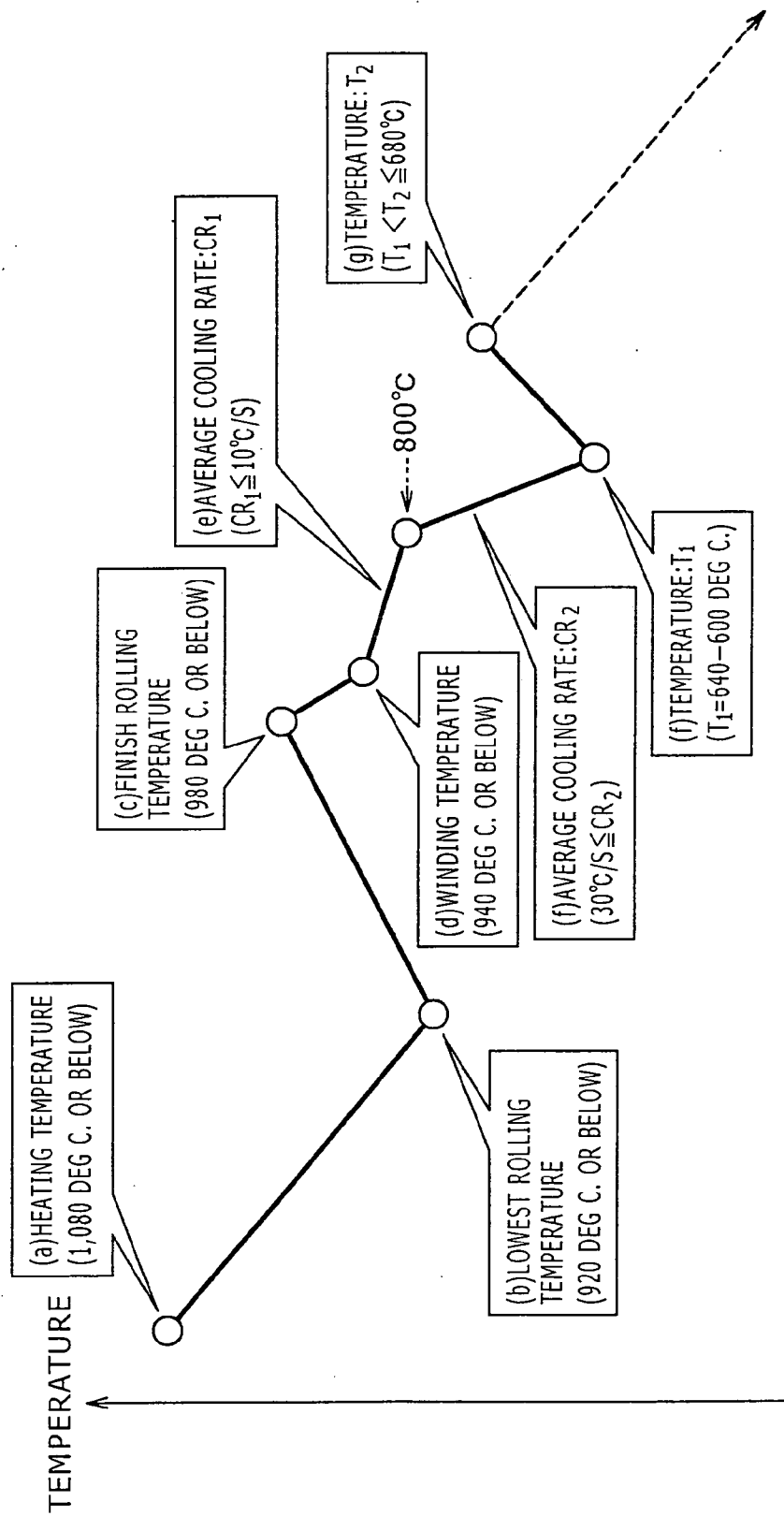
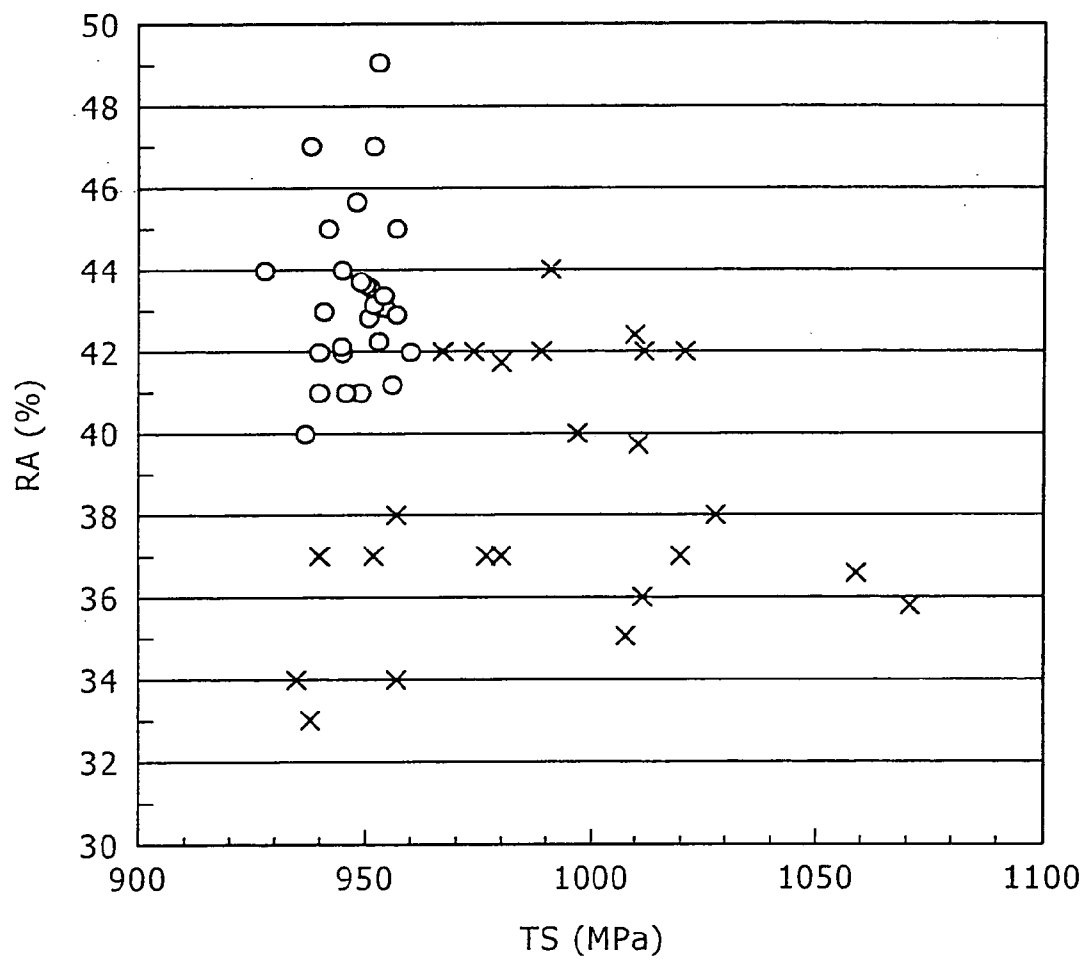


FIG. 2



REFERENCES CITED IN THE DESCRIPTION

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