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(54) METHOD OF PRODUCING STEEL WIRE

(57) Provided is a production method in which a steel having a good tensile strength can be produced with a small processing energy.

The method is a method of producing a steel wire, the method including: a pre-drawing process in which a high-carbon steel wire containing 0.90 to 1.20% by mass of carbon is subjected to a drawing to obtain an intermediate wire; a heat treatment process in which the intermediate wire is subjected to a patenting heat treatment to obtain a heat treated wire; and a final drawing process in which the heat treated wire is subjected to a drawing to obtain a steel wire, wherein the amount εf of drawing in the final drawing process which satisfies the relation represented by the following formula:

$$\varepsilon f = 2 \ln (D0/Df)$$

(wherein Df represents the final diameter of the steel wire obtained in the final drawing process, D0 represents the diameter of the heat treated wire before the final drawing process and In represents natural logarithm) is 2.50 to 3.10.

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Description

Technical Field

[0001] The present invention relates to a method of producing a steel wire (hereinafter, also simply referred to as "production method"), and particularly to a method of producing a steel wire in which the energy which is required for producing steel wire can be reduced.

Background Art

[0002] As a reinforcing member for tires and other rubber articles, a steel cord composed of, for example, steel wires twisted together is employed.

[0003] A high carbon steel wire used for this steel wire is conventionally produced by the following processes. Such a high carbon steel wire is made by using, as a raw material, a high carbon steel wire which has a pearlite structure by a Stelmor process having a diameter of about 5.5 mm. As a pre-drawing process, a drawing process is applied to the raw material to obtain an intermediate wire having a diameter larger than the final diameter. As the pre-drawing process, a dry drawing is generally applied, or in some cases, two drawing processes and a heat treatment therebetween are applied.

[0004] Further, as a heat treatment process, the intermediate wire is subjected to a patenting heat treatment to obtain a heat treated wire having a fine pearlite structure. In a case of producing a wire for reinforcing rubber particles, a brass plating process is applied followed by the heat treatment.

[0005] Still further, the heat treated wire is subjected to a drawing as the final drawing process to obtain a steel wire having a desired final diameter and a desired tensile strength. As such a final drawing process, a wet drawing method is generally applied.

[0006] The tensile strength of the steel wire produced by the above process is highly influenced by the composition of the raw materials (mainly the content of carbon) and the amount of drawing in the final drawing process. That is, the higher the content of carbon and the larger the amount of drawing in the final drawing process, a steel wire having the higher tensile strength can be obtained.

[0007] For example, the content of carbon in a raw material generally used for the production of a wire for steel cords is 0.80 to 0.86% by mass (hereinafter, referred to as "80C material"). The amount εf of drawing in the final drawing process which satisfies the relation represented by the following formula:

$$\varepsilon f = 2\ln(D0/Df)$$

(wherein Df represents the final diameter of the steel wire obtained in the final drawing process, D0 represents the diameter of the heat treated wire before the final drawing process and In represents natural logarithm) is about 3.2 when such a raw material is used to produce a steel wire having a diameter of 0.23mm and a tensile strength of about 3200 MPa. For such a general technique, a technique for a higher strength and a technique for reducing a production cost are demanded.

[0008] The Patent Documents 1 to 4 disclose a technique for increasing tensile strength by increasing the amount of final drawing by using 80C material and by improving the final drawing conditions. Patent Documents 5 and 6 disclose a technique for increasing tensile strength by using a raw material whose carbon content is increased and by adjusting the amount of drawing in the pre-drawing process in which an intermediate wire is produced. Further, Patent document 7 discloses a technique for increasing tensile strength by using a raw material whose carbon content is increased and by adding an alloy element such as Cr.

[0009] Still further, Patent Documents 8 and 9 disclose a technique of producing a steel wire having the same tensile strength as in the case where 80 C material is applied by using a raw material whose carbon content is less than that of 80 C material and by increasing the amount of final drawing.

Related Art Documents

Patent Documents

[0010]

Patent Document 1: Japanese Unexamined Patent Application Publication No. 8-132128 (Claims and the like)

Patent Document 2: Japanese Unexamined Patent Application Publication No. 8-218282 (Claims and the like)
Patent Document 3: Japanese Unexamined Patent Application Publication No. 10-325089 (Claims and the like)
Patent Document 4: Japanese Unexamined Patent Application Publication No. 11-241280 (Claims and the like)
Patent Document 5: Japanese Unexamined Patent Application Publication No. 6-136453 (Claims and the like)
Patent Document 6: Japanese Unexamined Patent Application Publication No. 2007-111767 (Claims and the like)
Patent Document 7: Japanese Unexamined Patent Application Publication No. 2008-69409 (Claims and the like)
Patent Document 8: Japanese Unexamined Patent Application Publication No. 8-260096 (Claims and the like)
Patent Document 9: Japanese Unexamined Patent Application Publication No. 8-325964 (Claims and the like)

Summary of the Invention

Problems to be Solved by the Invention

[0011] However, in the techniques in the Patent Documents 1 to 7, the energy required for the production is not taken into account among the current requirement for reduction of energy. In the techniques in the Patent Documents 8 and 9, while the cost of the raw material can be reduced, the energy required for the process is not reduced because the increase in the amount of the final drawing is needed, and a method of producing a steel wire in which a steel wire can be produced with a less processing energy is demanded.

[0012] Accordingly, an object of the present invention is to solve the problems in the above described conventional art and to provide a production method in which a steel wire having a good tensile strength can be produced with a small processing energy. Specifically, an object of the present invention is to provide a production method in which a steel wire having a similar tensile strength as a steel wire obtained by a conventional general production method using a 80 C material can be produced with a small processing energy.

Means for Solving the Problems

[0013] In order to solve the above problems, the present inventor intensively studied to discover the findings below.

[0014] That is, although, in the final drawing, a wet slip drawing method is usually employed, the drawing method of the wet drawing is a method in which a wire is pulled out in a lubricating liquid by a capstan. Here, taking into consideration the efficiency of production and equipment, it is preferred that about 20 steps of continuous drawings be conducted simultaneously by one wire drawing machine and the capstan in each of the steps be driven by one motor. However, because of its structure, the wire drawing machine requires a difference in speed between the capstan and a wire, i.e., a slip, which becomes a loss of power for production. On the other hand, the present inventor discovered that since the dry wire drawing machine used for the pre-drawing is a method in which the speed of one step of the capstan is controlled by one motor, a slip does not occur and a loss of power for production is small.

[0015] In the final wet drawing, because of an extreme pressure lubrication in which a plating on the surface of the wire is in contact by a metal-touch at the interface of the dice, the frictional coefficient is large. On the other hand, since, in the dry drawing, a powdery lubricant is introduced into the interface of a dice and a fluid lubricating state is generated by dissolving the lubricant, the frictional coefficient is thought to be small. For this reason, the power consumption in wet drawing is larger than that in dry drawing. The present inventor thus studied intensively further based on such findings to discover that a steel wire having a good tensile strength can be produced with a small processing energy by adjusting the amount εf of drawing in the final drawing process, thereby completing the present invention.

[0016] That is, the method of producing a steel wire of the present invention is a method of producing a steel wire, the method including: a pre-drawing process in which a high-carbon steel wire containing 0.90 to 1.20% by mass of carbon is subjected to a drawing to obtain an intermediate wire; a heat treatment process in which the intermediate wire is subjected to a patenting heat treatment to obtain a heat treated wire; and a final drawing process in which the heat treated wire is subjected to a drawing to obtain a steel wire, wherein the amount εf of drawing in the final drawing process which satisfies the relation represented by the following formula:

$$\varepsilon f = 2 \ln (D0/Df)$$

(wherein Df represents the final diameter of the steel wire obtained in the final drawing process, D0 represents the diameter of the heat treated wire before the final drawing process and In represents natural logarithm) is 2.50 to 3.10.

[0017] In the method of producing a steel wire of the present invention, the metal structure of the high-carbon steel wire is preferably pearlite, and further, the diameter of the steel wire obtained by the final drawing process is preferably 0.05 to 0.50 mm. Still further, in the method of producing a steel wire of the present invention, it is preferred that the

tensile strength TSf of the steel wire obtained in the final drawing process, the tensile strength TS of the heat treated wire and the εf satisfy the relation represented by the following formula:

$$TS \times \exp(0.24 \times \varepsilon f) \leq TSf \leq TS \times \exp(0.30 \times \varepsilon f) \ ,$$

and more preferably, TSf is 2700 to 3300 MPa.

[0018] In the method of producing a steel wire of the present invention, it is preferred that a high-carbon steel wire containing 0.90 to 1.05% by mass of carbon be subjected to a drawing to obtain an intermediate wire; the εf be 2.70 to 3.05; and the TSf be 2700 to 3200 MPa.

Effect of the Invention

[0019] By the present invention, a production method in which a steel wire having a good tensile strength can be produced with a small processing energy can be provided.

Modes for Carrying out the Invention

[0020] Modes of the present invention will now be specifically described.

[0021] The method of producing a steel wire of the present invention includes: a pre-drawing process in which a high-carbon steel wire is subjected to a drawing process to obtain an intermediate wire; a heat treatment process in which the intermediate wire is subjected to a patenting heat treatment to obtain a heat treated wire; and a final drawing process in which the heat treated wire is subjected to a drawing to obtain a steel wire.

[0022] In the method of producing a steel wire of the present invention, a high-carbon steel wire containing 0.90 to 1.20% by mass of carbon is used as a raw material, and a raw material in which an alloy element such as Cr, Ni or V is added to the high-carbon steel wire can also be used. When the amount of carbon contained in the high-carbon steel wire is less than 0.90% by mass, the amount of processing required in the final drawing process cannot be set much low compared with the case of applying a general 80 C material, and thus the energy-saving effect is small. On the other hand, when the amount of carbon contained in the high-carbon steel wire is more than 1.20% by mass, a uniform metal structure in the heat treatment process becomes hard to be obtained, and the drawability of the heat treated wire becomes poor.

[0023] Further, in the method of producing a steel wire of the present invention, the amount εf of drawing in the final drawing process which satisfies the relation represented by the following formula:

$$\varepsilon f = 2\ln(D0/Df)$$

(wherein Df represents the final diameter of the steel wire obtained in the final drawing process, D0 represents the diameter of the heat treated wire before the final drawing process and In represents natural logarithm) is 2.50 to 3.10, preferably 2.60 to 3.00. When the amount εf of drawing is less than 2.50, a tensile strength desired for a cord for reinforcing rubbers or a cord for ropes is hard to be obtained. On the other hand, when the amount εf of drawing is more than 3.10, the energy required for the final drawing becomes large, and an energy-saving effect is hard to be obtained.

[0024] An electric power need for the final drawing process largely accounts for the energy consumed in the production of a steel wire. For this reason, by adjusting the amount of drawing εf in the final drawing process, a steel wire having a good tensile strength can be produced with a small processing energy. By using a raw material whose carbon content is larger than that of a 80 C material, the amount of drawing needed in the final drawing process in order to obtain the same tensile strength as that of a conventional article can be made small, thereby reducing the energy needed for the production. Further, to make the amount of final drawing small is advantageous for improving the ductility of the steel wire, and accompanying effects such as improvement of productivity due to decrease of breaking of wire and improvement of the quality of steel wire can be expected.

[0025] In the method of producing a steel wire of the present invention, it is preferred that the metal structure of the high-carbon steel wire is pearlite. This is because the work hardening rate of the pearlite steel is larger that of martensite steel.

[0026] In the method of producing a steel wire of the present invention, it is preferred that the diameter of the steel wire obtained in the final drawing process be 0.05 to 0.50 mm. This range is a desired range of the diameter for a cord

for reinforcing rubbers or a cord for ropes, and by using this range, a steel wire having a good tensile strength can be produced with a small processing energy.

[0027] In the method of producing a steel wire of the present invention, it is preferred that, in a pearlite steel, the tensile strength TSf of the steel wire obtained in the final drawing process, the tensile strength TS of the heat treated wire and the εf satisfy the relation represented by the following formula :

$$TS \times \exp(0.24 \times \varepsilon f) \leq TSf \leq TS \times \exp(0.30 \times \varepsilon f) \quad ,$$

and more preferably, the TSf is 2700 to 3300 MPa. When the tensile strength of the steel wire is less than 2700 MPa, the strength of the steel wire for a cord for reinforcing rubbers or a cord for ropes may be insufficient, and on the other hand, when the tensile strength of the steel wire is more than 3300 MPa, it is needed that the amount of processing in the final drawing process be set large even when the carbon content is increased, and thus the energy-saving effect may be small.

[0028] Further, in the method of producing a steel wire of the present invention, it is preferred that a high-carbon steel wire containing 0.90 to 1.05% by mass of carbon be subjected to a drawing to obtain an intermediate wire; the amount εf of drawing be 2.70 to 3.05; and the tensile strength of the steel wire obtained in the final drawing process be 2700 to 3200 MPa. By this, a steel wire having a good tensile strength can be produced with a small processing energy. By setting the upper limit of the amount of carbon contained in the high-carbon steel wire to 1.05, it becomes easy to obtain a uniform metal structure in the heat treatment process.

[0029] In the present invention, only the carbon content in the high-carbon steel wire, the amount εf of drawing and the tensile strength of the steel wire obtained in the final drawing process are essential, and other processing methods, processing conditions or the like in each of the processes can be employed appropriately accordance with an ordinary method as required, and not particularly restricted.

[0030] The method of producing a steel wire of the present invention can be employed for a method of producing a cord for a steel cord for reinforcing rubber articles or a cord for a wire rope.

Examples

[0031] The present invention will now be further described in detail by way of examples thereof, and the present invention is not limited thereto in any way.

(Example 1)

[0032] A high-carbon steel wire (102 C material) having a diameter of 5.5 mm and containing 1.02% by mass of carbon was subjected to a drawing to produce an intermediate wire (pre-drawing process). The pre-drawing process was conducted without an intermediate heat treatment. The obtained intermediate wire was subjected to a patenting heat treatment to produce a heat treated wire (heat treatment process, heat treatment plating). The heat treated wire was subjected to a drawing (final drawing process), to obtain a steel wire of Example 1 having a diameter of 0.19 mm and having a tensile strength TSf of 3000 MPa. The metal structure of the high-carbon steel wire used is a virtually uniform pearlite structure.

[0033] In the Table 1 below, production conditions of the above Example 1 as well as the diameter of the intermediate wire (mm), the amount ε of drawing in the pre-drawing process, the tensile strength of the heat treated wire (TS, unit; MPa), the final diameter of the steel wire obtained in the final drawing process (mm), the amount εf of drawing in the final drawing process and the tensile strength of the steel wire obtained in the final drawing process (TSf, unit; MPa) were shown. In the Table 1, the carbon content (% by mass), diameter (mm) of the raw materials used and the abbreviation of the materials were shown. The amount ε of drawing is represented by the following formula:

$$\varepsilon = 2 \ln(D1/D2)$$

(wherein D1 represents the diameter of the wire before the pre-drawing process, D2 represents the diameter of the intermediate wire obtained in the pre-drawing process and In represents natural logarithm).

(Example 2)

[0034] A steel wire of Example 2 having a diameter of 0.19 mm and having a TSf of 3000 MPa was obtained in the

same manner as in Example 1 except that the production conditions shown in the Table 1 below were used.

(Conventional Example)

[0035] A steel wire of Conventional Example having a diameter of 0.19 mm and having a TSf of 3000 MPa was obtained in the same manner as in Example 1 except that the production conditions shown in the Table 1 below were used.

(Comparative Example 1)

[0036] A steel wire of Comparative Example 1 having a diameter of 0.19 mm and having a TSf of 3000 MPa was obtained in the same manner as in Example 1 except that the production conditions shown in the Table 1 below were used.

(Comparative Example 2)

[0037] A 90 C material was processed using the production conditions shown in the Conventional Example to obtain a steel wire of Comparative Example 2 having a diameter of 0.19 mm and having a TSf of 3350 MPa.

(Comparative Example 3)

[0038] A steel wire of Comparative Example 3 having a diameter of 0.19 mm and having a TSf of 3000 MPa was obtained in the same manner as in Example 1 except that the production conditions shown in the Table 1 below were used.

[Table 1]

	Example 1	Example 2	Conventional Example	Comparative Example 1	Comparative Example 2	Comparative Example 3
Raw material diameter	1.02% by mass (102 C material) 5.5mm	0.92% by mass (90 C material) 5.5mm	0.82% by mass (80 C material) 5.5mm	0.72% by mass (70 C material) 5.5mm	0.92% by mass (90 C material) 5.5mm	0.92% by mass (90 C material) 5.5mm
Intermediate wire diameter (mm)	0.70	0.85	0.93	1.03	0.93	0.90
Amount ε of drawing	4.12	3.73	3.55	3.35	3.55	3.62
TS (MPa)	1430	1370	1300	1200	1340	1350
Final diameter of steel wire (mm)	0.19	0.19	0.19	0.19	0.19	0.19
Amount εf of drawing	2.61	3.00	3.18	3.38	3.18	3.11
TSf (MPa)	3000	3000	3000	3000	3350	3000

[0039] The required energy for producing 1 t of each of the steel wires in Examples 1, 2, Conventional Example and

Comparative Examples 1 to 3 (energy in each of the processes and the total energy) was calculated respectively. The results are shown in Table 2 below using an index setting the total energy in the case of using a 80 C material to 1000. In the Table 2, the smaller the value, the smaller the required energy.

[Table 2]

	Example 1	Example 2	Conventional Example	Comparative Example 1	Comparative Example 2	Comparative Example 3
Pre-drawing process (index)	409	358	327	290	334	343
Heat treatment process (index)	150	150	150	150	150	150
Final drawing process (index)	374	468	523	562	534	502
Total (index)	933	976	1000	1002	1018	1005

[0040] While in the Conventional Example and the Comparative Examples 1 to 3, the rate of energy required in the final drawing process is large, since, in Examples 1 and 2, the energy required in the final drawing process of the high-carbon steel wire can be reduced, the energy required in the production can be reduced, and thus a steel wire having a good tensile strength could be produced with a small processing energy. In the above, the steel wires having a diameter of 0.19 mm and having a tensile strength of 3000 and 3350 MPa were exemplified. However, the same effect can be obtained in the production of a steel wire having a different diameter or a different tensile strength.

Claims

1. A method of producing a steel wire, the method including: a pre-drawing process in which a high-carbon steel wire containing 0.90 to 1.20% by mass of carbon is subjected to a drawing to obtain an intermediate wire; a heat treatment process in which the intermediate wire is subjected to a patenting heat treatment to obtain a heat treated wire; and a final drawing process in which the heat treated wire is subjected to a drawing to obtain a steel wire, wherein the amount εf of drawing in the final drawing process which satisfies the relation represented by the following formula:

$$\varepsilon f = 2 \ln (D0/Df)$$

(wherein Df represents the final diameter of the steel wire obtained in the final drawing process, D0 represents the diameter of the heat treated wire before the final drawing process and In represents natural logarithm) is 2.50 to 3.10.

2. The method of producing a steel wire of claim 1, wherein the metal structure of the high-carbon steel wire is pearlite.

3. The method of producing a steel wire of claim 1, wherein the diameter of a steel wire obtained in the final drawing process is 0.05 to 0.50 mm.

4. The method of producing a steel wire of claim 2, wherein the tensile strength TSf of the steel wire obtained in the final drawing process, the tensile strength TS of the heat treated wire and the εf satisfy the relation represented by

the following formula :

$$TS \times \exp(0.24 \times \varepsilon f) \leq TSf \leq TS \times \exp(0.30 \times \varepsilon f).$$

5. The method of producing a steel wire of claim 4, wherein the TSf is 2700 to 3300 MPa.

6. The method of producing a steel wire of claim 4 or 5, wherein a high-carbon steel wire containing 0.90 to 1.05% by mass of carbon is subjected to a drawing to obtain an intermediate wire; the εf is 2.70 to 3.05; and the TSf is 2700 to 3200 MPa.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/053352

A. CLASSIFICATION OF SUBJECT MATTER
B21C1/00(2006.01)i, *D07B1/06*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21C1/00, D07B1/06

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 1996-2010
Kokai Jitsuyo Shinan Koho 1971-2010 Toroku Jitsuyo Shinan Koho 1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2007-111767 A (Bridgestone Corp.), 10 May 2007 (10.05.2007), table 1; paragraphs [0024] to [0026]; claim 2 (Family: none)	1-6
X	JP 11-241280 A (Bridgestone Corp.), 07 September 1999 (07.09.1999), tables 8, 10, 12; paragraphs [0067] to [0076] (Family: none)	1-6

☐ 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
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"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
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Date of the actual completion of the international search	Date of mailing of the international search report
01 April, 2010 (01.04.10)	13 April, 2010 (13.04.10)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 8218282 A **[0010]**
- JP 10325089 A **[0010]**
- JP 11241280 A **[0010]**
- JP 6136453 A **[0010]**
- JP 2007111767 A **[0010]**
- JP 2008069409 A **[0010]**
- JP 8260096 A **[0010]**
- JP 8325964 A **[0010]**