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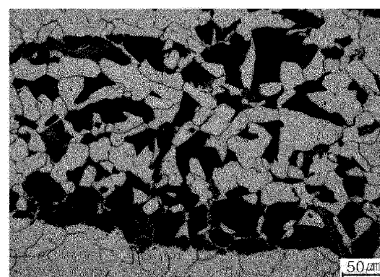
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(54) **WIRE ROD HAVING GOOD SUPERIOR SURFACE PROPERTIES, HIGH STRENGTH, AND HIGH TOUGHNESS, AND A METHOD FOR MANUFACTURING SAME**

(57) The present invention relates to a wire rod having high strength and high toughness, which suppresses the generation of surface oxide and has good superior surface properties through uniform oxide formation, and to a method for manufacturing same. For this purpose, According according to the present invention, a wire rod including comprising 0.005~ to 0.02 wtweight % of Sb, having good superior surface properties, high strength and high toughness, and a method for manufacturing same are provided.

(a)



(b)

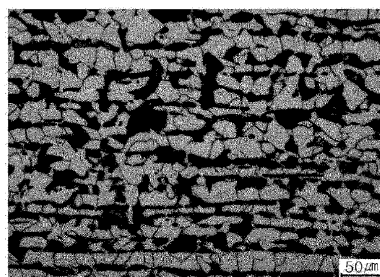


FIG. 1

EP 2 708 614 A2

Description

[Technical Field]

5 **[0001]** The present invention relates to a wire rod used in a structural steel, in particular, used in automobile components such as bolts, tie-rods and the like, requiring cold forging, and a method for manufacturing the same.

[Background Art]

10 **[0002]** Most structural steels may be heat treated steels formed by reheating, quenching and tempering steel after hot processing to increase the strength and toughness thereof. On the contrary, non-heat treated steel refers to steel having degrees of strength and toughness almost similar to those of a heat treated steel material, even without a heat treatment being performed thereon after hot processing. The term 'non-heat treated steel' is used in Korea and Japan and is also known as 'microalloyed steel' because a material thereof is formed by adding a small amount of an alloying element.

15 **[0003]** Meanwhile, since high strength steel is manufactured through tempering and thus, has a tensile strength of 900MPa or more and excellent ductility, such that it may be intended to be applied to components requiring impact resistance characteristics. However, in most steels, since when strength thereof is increased, ductility thereof may be lowered, the application thereof may be restricted.

20 **[0004]** In addition, an iron oxide unavoidably generated at the time of rolling wire rods may cause surface defects in the wire rod during wire drawing after the manufacturing of the wire rod to deteriorate quality thereof. Thus, there has been a process defect in which an iron oxide (scale) layer on the surface of the wire rod needs to be removed through post-processing such as pickling or the like, after the manufacturing of the wire rod. Thus, an increase in processing costs due to the removal of scale using water spraying or hot-scarfing in order to control the scale before hot rolling of the wire rod, during the manufacturing of the wire rod, has not been solved.

25 **[0005]** Meanwhile, in order to manufacture non-heat treated steel, in particular, non-heat treated steel having high strength and high ductility, controlled rolling and cooling processes through acceleration may be necessarily required in rolling and cooling operations, together with the addition of an alloying element such as titanium (Ti), vanadium (V), niobium (Nb) or the like. Such controlled rolling and cooling processes may be advantageous in that they may enable wire rods having minute particle sizes to be obtained, such that wire rods having excellent strength and ductility may be manufactured thereby. However, the controlled rolling and cooling processes may inevitably increase processing costs in accordance with an increase in the price of alloying elements and multiple process variations, and thus, the application thereof may be restricted.

30 **[0006]** With regard thereto, Japanese Patent Laid-Open Publication No. 2010-242170 discloses a technology of manufacturing bainite wire rods through a heat treatment after performing the addition of Cr, V, Ti, and B and rapid cooling. However, the technology has limitations in that processing costs are increased and a cooling device is further required. In addition, in Japanese Patent Laid-Open Publication No. 2010-222680, a non-heat treated wire rod having high strength may be manufactured through controlled rolling and cooling processes by adding Al, Cu, Ni, Mo, V or the like thereto, in order to control an initial austenite microstructure, but processing costs may inevitably be increased due to the necessity of further equipment installations. Further, Japanese Patent Laid-Open Publication No. 1998-008209 discloses that an alloying element such as Cr, V or the like is essentially added at the time of manufacturing a high strength and high toughness wire rod configured of ferrite and pearlite, but the effectiveness thereof is degraded due to the addition of an expensive alloying element in order to improve cold workability.

35 **[0007]** Thus, as described above, the limitations in increasing tensile strength and the solution to reducing a surface scale for manufacturing a high strength and high toughness wire rod are not overcome. A small number of patent applications relating to non-heat treated wire rods were filed in Japan, but in the patent applications, the addition of an expensive alloying element and controlled rolling and cooling are still essentially required, leading to an inability to secure a competitive price, and in particular, the removal of the surface scale is restricted.

40 **[0008]** Meanwhile, the world's prominent steel companies have conducted research into controlling oxides through the addition of inexpensive alloying elements capable of forming oxides to thereby obtain grain refining effects performable by the alloying elements. However, since most elements capable of forming oxides may be expensive and further, may be added in the same amount as that of a ferroalloy, the development of technologies thereof has been slow to progress.

45 **[0009]** Thus, a reduction in processing costs through the omission of a basic heat treatment requiring for the non-heat treated steel, the securing of price competitiveness through the addition of a tiny amount of elements capable of forming oxides, and the acquisition of rights to wire rods able to suppress surface defects thereof due to scale reduction may be indispensable in consideration of the speed of future development in the automobile industry.

55

[Disclosure]

[Technical Problem]

- 5 **[0010]** An aspect of the present invention provides a wire rod capable of having high strength and high toughness and suppressing the generation of a surface oxide, as well as having superior surface properties through uniform oxide formation, and a method for manufacturing the same.

[Technical Solution]

- 10 **[0011]** According to an aspect of the present invention, there is provided a wire rod having superior surface properties, high strength, and high toughness, the wire rod including: 0.005 to 0.02% of antimony (Sb), in terms of weight percentage.
[0012] According to another aspect of the present invention, there is provided a method for manufacturing a wire rod having superior surface properties, high strength, and high toughness, the method including: reheating steel including
 15 0.005 to 0.02% of antimony (Sb), in terms of weight percentage; wire rod-rolling the reheated steel at 700 to 1100°C; and performing cooling at a cooling rate of 0.5 to 2°C /s after the wire rod-rolling.

[Advantageous Effects]

- 20 **[0013]** According to embodiments of the present invention, in a method for manufacturing a wire rod having high strength and high toughness, surface defects of which are suppressed, a tensile strength and ductility of the wire rod may be increased while the refinement of grains thereof may be realized by forming oxides through the addition of a small amount of antimony (Sb), and a thickness of a final scale may be reduced by suppressing the growth of an iron oxide at high temperatures during hot rolling in a heating furnace and uniformly forming the iron oxide. Along with
 25 lightening and high functionalization of mechanical components, a wire rod according to embodiments of the present invention is manufactured using a generic technology for manufacturing a high strength and high ductility wire rod, and demand therefor is unlimited. In manufacturing a non-heat treated steel wire rod, the method for manufacturing a wire rod according to the embodiment of the present invention may have predominance in terms of price competitiveness through the omission of relatively expensive alloying elements, tensile strength, and surface qualities, as compared to
 30 those of the existing competing products, and may be a generic technology in that it provides a novel manufacturing method having no process condition limitations.

[Description of Drawings]

- 35 **[0014]**

FIG. 1 shows photographs illustrating microstructures of the related art steel and inventive steel 1 according to an embodiment of the present invention.

- FIG. 2 shows photographs illustrating antimony (Sb) oxides of inventive steel 1 according to the embodiment of the
 40 present invention.

FIG. 3 is a graph showing results of Table 2.

[Best Mode]

- 45 **[0015]** Hereinafter, embodiments of the present invention will be described in greater detail.
[0016] According to an embodiment of the present invention, a small amount of antimony (Sb) is included at the time of manufacturing of a wire rod, such that grain size growth of austenite grains may be suppressed and the formation of an oxide on a surface of the wire rod may be adjusted through a structure control using antimony (Sb) oxides to improve strength and toughness of the wire rod. Further, the formation of an iron oxide (scale) on the surface of the wire rod may
 50 be suppressed to enable a thin, uniform oxide to be formed, thereby reducing surface defects.
[0017] First, the wire rod according to the embodiment of the present invention will be described in detail.
[0018] The wire rod according to the embodiment of the present invention may include 0.005 to 0.02% of antimony (Sb), in terms of weight percentage. The antimony (Sb), an element playing a key role in the embodiment of the present invention, may enable antimony (Sb) oxides (commonly Sb_2O_5) to be formed in an austenitic base structure to suppress
 55 the growth of grain boundaries and suppress the formation of the iron oxide, thereby allowing for a fine final surface of the wire rod.
[0019] When the antimony (Sb) is included in an amount less than 0.005%, an amount thereof reacting with oxygen may be insufficient, such that thermodynamically sufficient antimony (Sb) oxides may not be formed, to lead to a failure

to form a solid solution in the form of antimony (Sb) metal, thereby leading to difficulties in oxide formation. When the antimony (Sb) is included in an amount greater than 0.02%, an excessive amount of antimony (Sb) beyond an amount thereof capable of forming oxygen affinity is added and may be eluted into the austenitic base structure, in the form of solute atoms, thereby causing breakage to the wire rod during wire drawing and simultaneously, rapidly degrading cold forging properties. Thus, it may be necessary to limit the amount of antimony (Sb).

[0020] Meanwhile, the wire rod according to the embodiment of the present invention may not include precipitate elements added thereto, in addition to antimony (Sb). The precipitate elements may representatively include titanium (Ti), niobium (Nb), vanadium (V) and the like. In the case of adding Ti and Sb in combination, oxygen in molten steel may first react with Ti to extract TiO_2 , such that antimony (Sb) oxides may not be effectively generated and grain refining effects may not be obtained. Moreover, in the case of adding Nb or V, it may be advantageous in terms of the refinement of austenite grains, but a cost increase may be inevitably generated. Further, since Nb or V may easily react with oxygen and hinder the antimony (Sb) oxides from being formed, effective grain refining effects may not be obtained.

[0021] Meanwhile, in the wire rod according to the embodiment of the present invention, components other than antimony (Sb) are not particularly limited, as long as they are components for a general structural wire rod. By way of example, the wire rod according to the embodiment of the present invention may further include C: 0.25 to 0.45%, Si: 0.1 to 0.2%, and Mn: 0.1 to 0.7%, in terms of weight percentage, in addition to the antimony (Sb).

[0022] The components are limited due to the following reasons.

[0023] Carbon (C) may be an element ensuring a strength of steel. When carbon (C) is included in an amount less than 0.25%, the strength may not be easily ensured, while carbon (C) is included in an amount greater than 0.45%, it may cause cracks in or breakage to the wire rod during a rolling or wire drawing process.

[0024] Silicon (Si) may be dissolved in ferrite to reinforce strength of a basic material. When silicon (Si) is included in an amount less than 0.1%, the strength may be insufficiently increased through the dissolution, while when silicon (Si) is included in an amount greater than 0.2%, work hardening effects may be increased during cold forging to cause a deterioration in toughness.

[0025] Manganese (Mn) may increase strength of steel and reinforce rolling properties, while decreasing brittleness. When manganese (Mn) is included in an amount less than 0.1%, strength reinforcement may be incomplete while when manganese (Mn) is included in an amount greater than 0.7%, a hardening phenomenon according to the increased strength may be intensified.

[0026] It may be obvious that the addition components, other than the above-described components, is not excluded and the remainder may include Fe and inevitable impurities.

[0027] The wire rod according to the embodiment of the present invention may include the antimony (Sb) oxides and the form of the antimony (Sb) oxides may commonly be Sb_2O_5 . The antimony (Sb) oxides may suppress the growth of grain boundaries using the drag effect in which the growth of grains is controlled through the extraction of the grain boundaries, to refine ferrite and pearlite grains, thereby increasing the tensile strength and ductility of the wire rod. Meanwhile, the antimony (Sb) oxides may suppress the growth of the iron oxide at high temperatures during hot rolling in a heating furnace and allow for the uniform formation of iron oxide, to reduce a thickness of a final scale, thereby suppressing surface defects.

[0028] An average grain diameter of the antimony (Sb) oxides may be 20 to 50 nm. The antimony (Sb) oxides may be provided to control grain diameters of ferrite and pearlite through the growth of grains thereof. In order to optimize grain boundary pinning effects, the antimony (Sb) oxides may have an average grain diameter of 20 to 50 nm.

[0029] An amount of the antimony (Sb) oxides distributed per unit area (μm^2) in the wire rod may be 50 to 100. When an amount of the antimony (Sb) oxides distributed in the unit area is greater than 100, since the extraction may be performed from within the grains, as well as from the grain boundaries, the strength is rapidly increased, leading to a reduction in ductility. When the number of the antimony (Sb) oxides distributed in the unit area is less than 50, the pinning effects may be insufficient to deteriorate the strength. Thus, 50 to 100 antimony (Sb) oxides per unit area (μm^2) may be preferable.

[0030] The microstructure of the wire rod according to the embodiment of the present invention may include ferrite and pearlite. In the microstructure of the wire rod, a relative area of ferrite may be 70% or more and pearlite may occupy the remainder of the area thereof.

[0031] An average grain size of ferrite may be 10 to $20\mu\text{m}$ and an average grain size of pearlite may be 20 to $25\mu\text{m}$.

[0032] A fraction of the microstructure may correlate with strength and ductility. That is, since the ductility is high in accordance with an increase in ferrite fraction, in a case in which the relative area of ferrite having a small average grain size is large, strength and ductility may be simultaneously increased. Thus, the grain size and the fraction may be restricted.

[0033] When the grain size of ferrite is greater than $20\mu\text{m}$, since sizes of the grains are large, the ductility is increased while the strength may be insufficiently reinforced. When the grain size of ferrite is less than $10\mu\text{m}$, the grains may be changed into ultrafine grains to inevitably lead to a deterioration in ductility according to an increase in strength. Thus, the average grain size of ferrite may be 15 to $20\mu\text{m}$.

[0034] In a similar manner, when the ferrite fraction is less than 70%, since the ductility may not be reinforced in accordance with the increase in strength, the ferrite fraction may be 70% or more.

[0035] The wire rod according to the embodiment of the present invention may have the iron oxide (scale) formed on the surface thereof at a thickness of 20 to 150 μ m. When the thickness of the scale is less than 20 μ m, since coupling force between the surface of the wire rod and the scale may be significantly strong, a separate device such as a water sprayer or the like may be required in order to remove the scale. Moreover, even at the time of removing the scale using a device, such as hot-scarfing or the like, since the thickness of the scale is significantly small, defects may be generated in the surface of the wire rod. Meanwhile, when the thickness of the scale is large, greater than 150 μ m, time and process conditions for removing the scale are additionally required, thereby leading to an increase in processing costs. Despite such processing, the wire rod having a fine surface may not be obtained due to the thick scale.

[0036] Thus, when the thickness of the scale is 20 to 150 μ m, wire drawing may be performed using the scale itself due to the scale having an adequate thickness, and further, the wire rod having a fine surface due to the removal of the scale may be advantageously manufactured.

[0037] The wire rod according to the embodiment of the present invention may have a tensile strength of 600 to 900 MPa and an elongation of 25% or more.

[0038] Hereinafter, a method for manufacturing the wire rod according to the embodiment of the present invention will be described in detail.

[0039] In order to manufacture the wire rod according to the embodiment of the present invention, steel including 0.005 to 0.02% of antimony (Sb) in terms of weight percentage may be reheated. The reheating may be provided to realize a homogenizing treatment, and a temperature therefor may be 1100 °C or more.

[0040] The reheated steel may be hot rolled. The hot rolling may be a wire rod-hot rolling and may be undertaken at a temperature of 900 to 1100°C, preferably, 800 to 1050°C. At the time of hot rolling, when the rolling temperature is less than 900°C, rolling may be performed in a two-phase area to cause a drop in pressure, thereby leading to a rapid rolling of the structure, such that a spreading rate of oxygen may be insufficient, causing difficulties in the extraction of the antimony (Sb) oxides. When the temperature is greater than 1100°C, the antimony (Sb) oxides may be completely dissolved during the rolling, but they may not be effectively spread to grain boundaries to result in an increase in precipitate sizes.

[0041] The wire rod manufactured through the rolling may be cooled at a cooling rate of 0.5 to 2°C/s. When the cooling rate is less than 0.5°C/s, due to an aging phenomenon for degrading surface energy between the extracted antimony (Sb) oxides, the wire rod may be configured of ferrite and pearlite, structures of which are elongated, and grain orientations which are varied, thereby causing impacts due to structural anisotropy and deteriorated ductility. In addition, due to the aging phenomenon, the strength of an as-rolled wire rod may be naturally increased to deteriorate ductility. Meanwhile, when the cooling rate is equal to or greater than 2°C/s, even in a case in which the wire rod is a medium carbon steel wire rod, martensite may be formed on the surface of the wire rod in accordance with a lowering of the martensite transformation point to thereby exhibit brittleness. Thus, the cooling rate may be restricted.

[0042] The aging phenomenon according to a degradation in the cooling rate may cause structural anisotropy, and since martensite, a low-temperature structure, may be formed in the wire rod in the case of a cooling rate greater than 2°C/s, the cooling rate may be 0.5 to 2°C/s.

[0043] Additionally, wire drawing may be performed on the wire rod, such that a wire rod may be manufactured.

[Mode for Invention]

[0044] Hereinafter, examples according to the embodiment of the present invention will be described in detail. The following examples are merely provided for comprehension of the present invention, and the present invention is not limited thereto.

(Examples)

[0045] Steels satisfying compositions of Table 1 were prepared and subjected to a solution heat treatment at 1100°C. Next, after strain was applied to the steels at a strain rate of 0.6 and 10/s at 950°C, cooling was performed thereon at a cooling rate of 2°C/s. Then, wire drawing was performed thereon at 10 to 80%, such that wire rods were manufactured.

[Table 1]

Classificat ion	C	Si	Mn	P	S	Sb	The remainder
Inventive steel 1	0.25	0.15	0.6	0.2	0.015	0.005	Fe
Inventive steel 2	0.25	0.15	0.6	0.2	0.015	0.015	Fe

(continued)

Classification	C	Si	Mn	P	S	Sb	The remainder
Inventive steel 3	0.25	0.15	0.6	0.2	0.015	0.02	Fe
The related art steel	0.25	0.25	0.6	0.2	0.015	-	Fe
Comparative Steel 1	0.25	0.15	0.6	0.2	0.015	0.002	Fe
Comparative Steel 2	0.25	0.15	0.6	0.2	0.015	0.05	Fe

[0046] FIG. 1A and FIG. 1B respectively show microstructures of the related art steel and inventive steel 1, observed using an optical microscope. As shown in FIG. 1, the related art steel had a ferrite-pearlite structure, but a ferrite fraction thereof was less than 40% and a structure size thereof was about 35 to 50 μ m. On the other hand, in the case of inventive steel 1, it can be confirmed that the ferrite fraction was 40% or more and the structure size was minute, in a range of 20 to 25 μ m.

[0047] In addition, FIG. 2A shows antimony (Sb) oxides of inventive steel 1. As illustrated in FIG. 2A, it could be confirmed that the antimony (Sb) oxides were formed as nano-sized oxides. Further, 50 to 100 antimony (Sb) oxides per unit area were distributed. According to the embodiment of the present invention, an adequate amount of minute antimony (Sb) oxides as described above were distributed to suppress the initial grain growth of austenite grains due to grain boundary pinning effects, thereby reducing an average grain size of ferrite. Thus, it could be confirmed that inventive steel 1 ensured a high degree of strength and toughness in accordance with an increase in the content of minute ferrite grains.

[0048] Wire drawing was performed on the wire rods manufactured according to Table 1 to manufacture wire rods. With respect to the manufacture respective wire rods, tensile strength and elongation were measured according to an amount of wire drawing, and the measured results are shown in Table 2 and FIG. 3.

[Table 2]

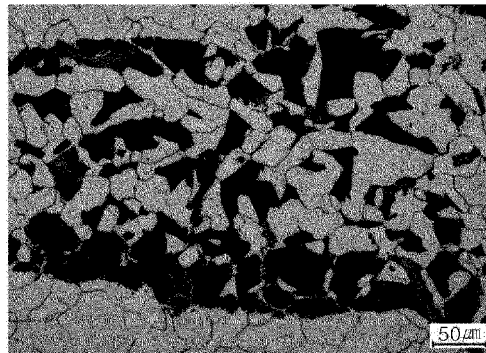
Amount of wire drawing (%)	Tensile strength (MPa)							Elongation (%)						
	Inventive steel 1	Inventive steel 2	Inventive steel 3	Related art steel	Comparative Steel 1	Comparative Steel 2		Inventive steel 1	Inventive steel 2	Inventive steel 3	Related art steel	Comparative Steel 1	Comparative Steel 2	
10	629. 7	613	607. 9	550	548. 3	567. 6		31.2	30.3	28.9	26.2	26.6	25.9	
20	702. 1	655. 3	642. 9	578. 5	553. 2	585. 9		29.9	29.6	27.5	25.4	25.6	24.3	
30	742. 2	714. 4	687. 7	620. 3	562. 5	619. 8		29.1	28.5	27.2	24.8	24.2	24.5	
40	778. 6	742. 2	715. 5	638. 9	598. 1	635. 6		28.6	28.6	26.3	24.7	24.7	23.9	
50	836. 9	789. 6	762. 2	655. 8	602. 1	659. 1		27.9	27.5	26.1	23.5	24.2	22.1	
60	887. 5	826. 4	796. 4	666. 8	632. 9	678. 5		27.5	27.1	25.5	22.1	23.3	20.6	
70	925. 3	866. 6	825. 2	675. 2	644. 6	682. 6		27.5	26.8	25.3	21.9	22.7	21.6	
80	936. 8	897. 2	856. 4	683. 3	653. 7	689. 6		26.8	26.5	25.1	21.2	21.3	20.1	

[0049] As illustrated in Table 2 and FIG. 3, in the inventive steels according to the embodiment of the present invention, strength thereof was increased in accordance with an increase in the amount of wire drawing, while excellent elongation was secured. That is, in the inventive steels according to the embodiment of the present invention, 25% or more of elongation was secured in the case of 80% of wire drawing. However, in the case of the related art steel or comparative steels, it could be confirmed that the strength was marginally exhibited and elongation was rapidly degraded.

Claims

1. A wire rod having superior surface properties, high strength, and high toughness, the wire rod comprising: 0.005 to 0.02% of antimony (Sb), in terms of weight percentage.
2. The wire rod of claim 1, wherein the wire rod includes antimony (Sb) oxides, the antimony (Sb) oxides including Sb_2O_5 .
3. The wire rod of claim 2, wherein the antimony (Sb) oxides have an average grain diameter of 20 to 50 nm.
4. The wire rod of claim 2, wherein an amount of the antimony (Sb) oxides distributed per μm^2 is 50 to 100.
5. The wire rod of claim 1, further comprising carbon C: 0.25 to 0.45%, Si: 0.1 to 0.2%, and Mn: 0.1 to 0.7%, in terms of weight percentage.
6. The wire rod of claim 1, wherein in a microstructure of the wire rod, a relative area of ferrite is 70% or more and pearlite occupies a remainder of the area thereof.
7. The wire rod of claim 6, wherein an average grain size of ferrite is 10 to 20 μm and an average grain size of pearlite is 20 to 25 μm .
8. The wire rod of claim 1, wherein the wire rod has scale formed on a surface thereof at a thickness of 20 to 150 μm .
9. The wire rod of claim 1, wherein the wire rod has a tensile strength of 600 to 900 MPa and an elongation of 25% or more.
10. A method for manufacturing a wire rod having superior surface properties, high strength, and high toughness, the method comprising:
 - reheating steel including 0.005 to 0.02% of antimony (Sb), in terms of weight percentage;
 - wire rod-rolling the reheated steel at 700 to 1100°C; and
 - performing cooling at a cooling rate of 0.5 to 2°C /s after the wire rod-rolling.
11. The method of claim 10, wherein the steel further includes C: 0.25 to 0.45%, Si: 0.1 to 0.2%, and Mn: 0.1 to 0.7%, in terms of weight percentage.
12. The method of claim 10, further comprising: performing wire drawing after the performing of cooling.

(a)



(b)

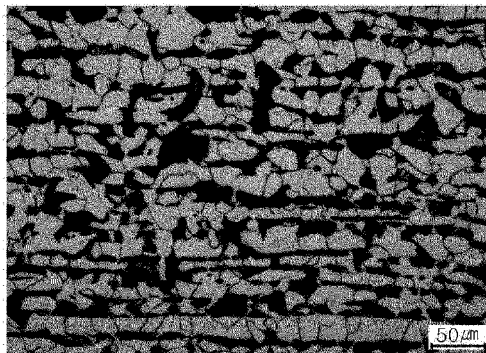


FIG. 1

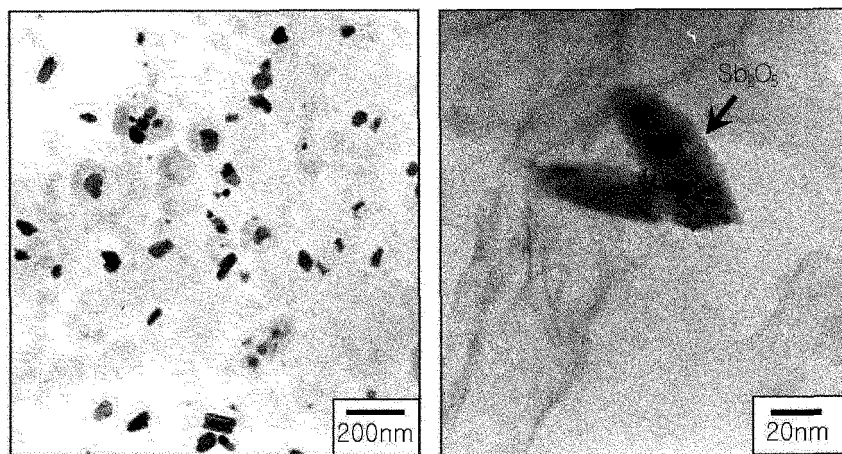


FIG. 2

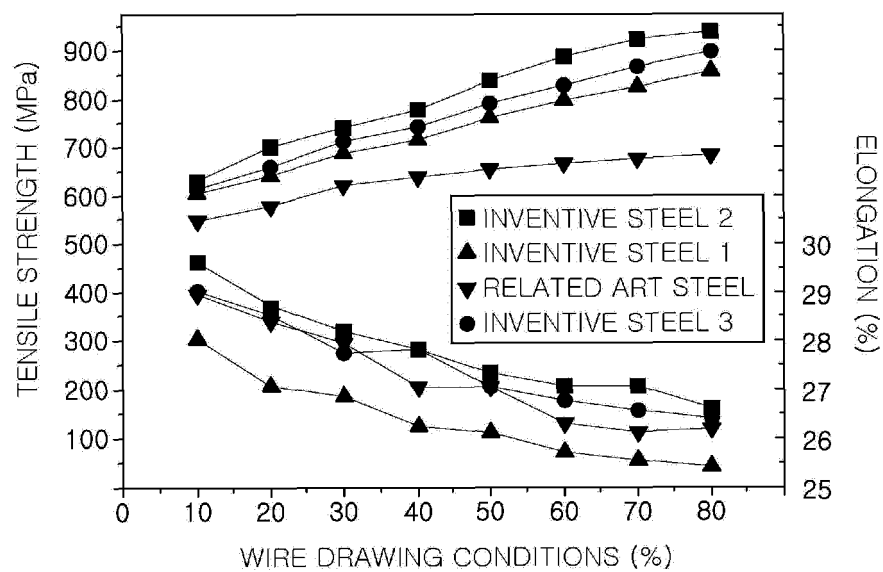


FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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