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(54) Method for removing rust from a rusted steel

(57) A method for removing rust from a rusted steel includes: (a) subjecting the rusted steel to an electrolytic treatment in an electrolytic bath of an alkaline electrolyte solution that contains tartrate, the tartrate in the alkaline electrolyte solution having a molar concentration equal to or greater than 0.4M,the rusted steel serving as an anode in the electrolytic bath, the electrolytic treatment being conducted by applying a current with a current density equal to or greater than 10 A/dm^2 across the electrolytic bath; and (b) applying a mechanical force to the rusted steel after step (a) so as to remove rust from the rusted steel.

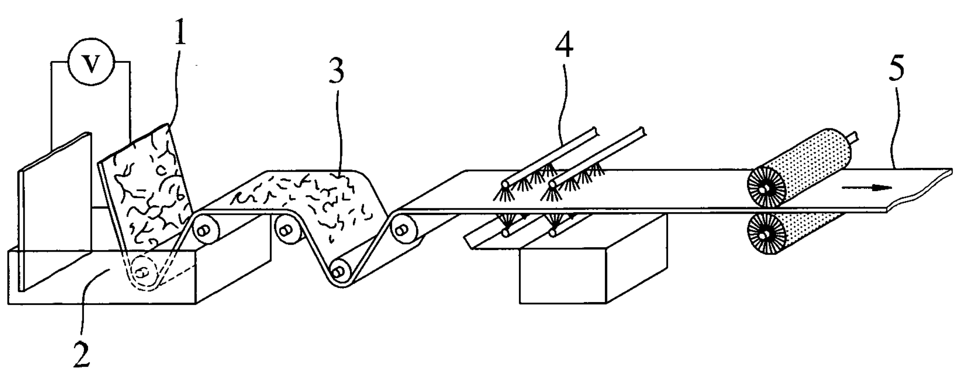

FIG.1

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Description

[0001] This invention relates to a method that involves subjecting a rusted steel to an electrolytic treatment in a bath of an alkaline electrolyte solution that contains tartate, and applying a mechanical force to the rusted steel.

[0002] During manufacturing, steels, such as stainless steel, carbon steel, and alloy steel, are normally subjected to a heat treatment, such as annealing or hot-rolling, which tends to cause formation of rust (or scale) of metal oxides, such as iron oxide, nickel oxide or chromium oxide, on a surface of the steel. The rust has an adverse effect on the subsequent processing of the steel, and is required to be removed.

[0003] Various methods of removing the rust have heretofore been proposed. Among them, acid pickling is relatively efficient in removing the rust from steel. The acid pickling can be combined with one or more auxiliary treatments, such as salt bath, electrolysis, mechanical descaling operation, etc., to improve the rust removing efficiency.

[0004] Acid pickling is conducted by using an acidic solution containing an acid, such as sulfuric acid, nitric acid, hydrochloric acid, phosphoric acid, or combinations thereof. Acid pickling normally has the problem of incomplete pickling or excessive pickling, and tends to generate undesired holes in the surface of the steel and serious pollution problem.

[0005] US Patent No. 5,897,764 discloses a method for removing scale from a surface of a high-grade steel strip in installations for production of pickled hot strip and cold strip. The conventional method combines an acidic electrolytic pickling process with an ultrasonic cleaning of the strip surface. Although the amount of the acidic electrolyte solution employed in the conventional method can be reduced, the use of the acidic electrolyte solution undesirably generates heavy metal ions, which results in difficulty in recycling or disposal of the acidic electrolyte solution.

[0006] Therefore, an object of the present invention is to provide a method for removing rust from a rusted steel that can overcome at least one of the aforesaid drawbacks associated with the prior art.

[0007] According to the present invention, there is provided a method for removing rust from a rusted steel. The method comprises: (a) subjecting the rusted steel to an electrolytic treatment in an electrolytic bath of an alkaline electrolyte solution that contains tartrate, the tartrate in the alkaline electrolyte solution having a molar concentration equal to or greater than 0.4M, the rusted steel serving as an anode in the electrolytic bath, the electrolytic treatment being conducted by applying a current with a current density equal to or greater than 10 A/dm^2 across the electrolytic bath; and (b) applying a mechanical force to the rusted steel after step (a) so as to remove rust from the rusted steel.

[0008] In drawings which illustrate an embodiment of the invention,

- Fig. 1 is a schematic view illustrating a rust removing system for a method of removing rust from a rusted steel according to the present invention;
- Fig. 2 is an SEM photograph showing the degree of rust cracking of Example 2 (conducted by applying a current with a current density 60 A/dm^2);
- Fig. 3 is an SEM photograph showing the degree of rust cracking of Example 3 (conducted by applying a current with a current density 80 A/dm^2);
- Fig. 4 is an SEM photograph showing the degree of rust cracking of Example 4 (conducted by applying a current with a current density 100 A/dm^2);
- Fig. 5 is an SEM photograph illustrating the degree of cracking of the untreated rusted steel of Comparative Example 3; and
- Fig. 6 is a table of pictures, illustrating the appearances of treated and untreated rusted steel wires of Examples 12 to 17.

[0009] The method of the preferred embodiment of this invention for removing rust (or scale) from a rusted steel comprises: (a) subjecting the rusted steel to a first electrolytic treatment in a first electrolytic bath of a first alkaline electrolyte solution that contains tartrate, the tartrate in the first alkaline electrolyte solution having a molar concentration equal to or greater than 0.4M, the rusted steel serving as an anode in the first electrolytic bath, the first electrolytic treatment being conducted by applying a current with a current density equal to or greater than 10 A/dm^2 across the first electrolytic bath; and (b) applying a mechanical force to the rusted steel after step (a) so as to remove rust from the rusted steel.

[0010] During the first electrolytic treatment, the rust is dissociated into metal ions, which subsequently react with hydroxyl ions in the first electrolytic bath to form precipitates of metal oxides and/or metal hydroxides. The precipitates may be easily removed from the first electrolytic bath by filtration, so that the first alkaline electrolyte solution may be recycled. In addition, grease on the surface of the rusted steel may also be removed during the first electrolytic treatment. Hence, a degreasing operation prior to the acid pickling in the conventional method may be omitted.

[0011] Examples of the steel include stainless steel, carbon steel, and alloy steel. In the preferred embodiment, the rusted steel is stainless steel. The rusted steel may be in the form of a plate, a rod or a wire.

[0012] In step (a), the first electrolytic treatment is conducted by using a conventional electrolysis apparatus.

[0013] The tartrate is preferably selected from the group consisting of sodium tartrate, potassium tartrate, sodium potassium tartrate, and combinations thereof, and more preferably is sodium tartrate. Preferably, the sodium tartrate in the first alkaline electrolyte solution has a molar concentration ranging from 0.8 to 1.0M.

[0014] The first electrolytic treatment in step (a) is capable of forming a plurality of cracks in the rust on the rusted steel by the reaction of tartrate ions, dissociated from the tartrate, with the rust, thereby destroying the structure of the rust on the rusted steel.

[0015] The first alkaline electrolyte solution preferably has a pH ranging from 7 to 8.5, and more preferably from 7.5 to 8.0. In the preferred embodiment of the present invention, the first alkaline electrolyte solution has a pH ranging from 7.8 to 8.0.

[0016] The first alkaline electrolyte solution may optionally include suitable additives depending on the actual requirements. Examples of the additives may include surfactants, metal chelating agents, etc. Preferably, the metal chelating agent is selected from the group consisting of citric acid, sodium chloride, oxalic acid, malonic acid, nitric acid and combinations thereof. More preferably, the metal chelating agent is selected from the group consisting of citric acid, sodium chloride and the combination thereof.

[0017] When the current density is lower than 10 A/dm^2, the structure of the rust may not be destroyed and removed from the rusted steel. Preferably, the first electrolytic treatment is conducted by applying a current with a current density ranging from 20 to 100 A/dm^2 across the first electrolytic bath. When the current density is higher than 100 A/dm^2, unnecessarily excessive power consumption occurs and the electrolysis apparatus may be damaged due to overheating. The current density more preferably ranges from 40 to 100 A/dm^2, and most preferably ranges from 60 to 100 A/dm^2.

[0018] Preferably, the first electrolytic treatment in step (a) is conducted under a temperature ranging from 30 to 70°C, more preferably from 60 to 70°C.

[0019] Preferably, the time period of the first electrolytic treatment ranges from 60 to 300 seconds. In the preferred embodiment of the present invention, the time period is 120 seconds.

[0020] Preferably, the method for removing the rust from the rusted steel of the present invention further comprises subjecting the rusted steel to a second electrolytic treatment in a second electrolytic bath of a second alkaline electrolyte solution that contains trisodium phosphate after step (a) and before step (b), with the rusted steel serving as an anode.

[0021] The trisodium phosphate in the second electrolytic bath is dissociated into phosphate ions. The phosphate ions can react with the rust, and enters the cracks in the rust to react with the underlying steel, which facilitates separation of the rust from the steel and permits formation of a matte appearance on the surface of the steel.

[0022] Preferably, the second alkaline electrolyte solution has a pH ranging from 8 to 13.

[0023] Preferably, the trisodium phosphate in the second alkaline electrolyte solution has a molar concentration ranging from 0.2 to 0.6M.

[0024] The second alkaline electrolyte solution may optionally include suitable additives depending on the actual requirements. The additives may include surfactants, metal chelating agents, etc. Preferably, the metal chelating agent is selected from the group consisting of citric acid, sodium chloride, oxalic acid, malonic acid, nitric acid and combinations thereof. More preferably, the metal chelating agent is selected from the group consisting of citric acid, sodium chloride and the combination thereof. The amount of the metal chelating agent may be optionally adjusted depending on the actual requirements. Preferably, the metal chelating agent is used in an amount ranging from 10 parts by weight to 25 parts by weight based on 100 parts by weight of the second alkaline electrolyte solution.

[0025] Preferably, the second electrolytic treatment is conducted by applying a current with a current density ranging from 20 to 160 A/dm^2 across the second electrolytic bath. When the current density is lower than 20 A/dm^2, the second electrolytic treatment has no impact on the rust. When the current density is higher than 160 A/dm^2, unnecessarily excessive power consumption occurs and the electrolysis apparatus may be damaged due to overheating. The current density preferably ranges from 20 to 100 A/dm^2, more preferably ranges from 40 to 100 A/dm^2, and most preferably ranges from 60 to 100 A/dm^2.

[0026] Preferably, the second electrolytic treatment is conducted under a temperature ranging from 30 to 70 °C, more preferably from 60 to 70°C.

[0027] Preferably, the time period of the second electrolytic treatment ranges from 60 to 180 seconds. In the preferred embodiment of the present invention, the time period is 60 seconds.

[0028] Preferably, the first alkaline electrolyte solution further contains polyethylene glycol. When the first alkaline electrolyte solution contains polyethylene glycol, the surface tension of water in the first electrolytic bath may be reduced, which may result in an increase in adsorption activity of the first alkaline electrolyte solution to the surface of the rusted steel and which may permit a stable electrolytic operation.

[0029] Preferably, the mechanical force is applied to the rusted steel by brushing, wiping, ultrasonic vibration, or combinations thereof. More preferably, the mechanical force is applied to the rusted steel by the combination of brushing and ultrasonic vibration.

[0030] Fig. 1 illustrates a rust removing system that may be used in the method of the present invention. The rust removing system includes: a plurality of rollers for conveying a continuous sheet of the rusted steel 1; an electrolytic bath 2 with a power source connected to a cathode and an anode defined by the continuous sheet 1; a water-jet blowing device 3 for providing the mechanical force 3 to the continuous sheet 1 passing through the electrolytic bath 2; and a pair of calender rollers for calendering the continuous sheet.

[0031] The merits of the method for removing the rust from the rusted steel of this invention will become apparent with reference to the following Examples and Comparative Examples. The method of this invention should not be restricted to the following Examples.

<Examples>

<Example 1 (EX1)>

[0032] A rusted steel wire (purchased from Walsin company, catalog no.: SS316. having a diameter of 5.5 mm and a length of 50 mm), having a layer of rust with a thickness of 20μm, was prepared.

[0033] The rusted steel wire was subjected to a first electrolytic treatment in a first electrolytic bath of a 0.5M sodium tartrate solution (pH 7.8), and was used as an anode of the first electrolytic bath. A titanium plate was used as a cathode of the first electrolytic bath. A power source was electrically connected to the cathode and the anode. The first electrolytic treatment was conducted by applying a current with a current density of $40A/dm^2$ across the first electrolytic bath under a temperature 31°C.

[0034] After electrolyzing for 120 seconds, a structure of the rust on the rusted steel was destroyed (i.e., cracks were formed in the rust and the bonding strength of the rust on the steel wire was significantly weakened). The rusted steel wire was then placed into an ultrasonic oscillator for oscillation for 60 seconds, followed by brushing with a cloth (Manufactured by 3M company, catalog no.: 8501) to obtain a surface treated steel wire of Example 1. The surface-treated steel wire was examined by counting a percentage of the rust removed from the surface of the surface-treated steel wire. The percentage is determined by dividing the surface of the surface treated steel wire into 100 square units of the same area, followed by counting the number of the square units that are free of the rust through observation. The degree of rust removal indicated by characters "A", "B", "C", and "D" in Tables 1 to 3 and 5 to 7 represent percentage ranges above 90%, above 85% to 90%, 80-85%, and below 80%, respectively. The conditions for the first electrolytic treatment and the examination results (degree of removal of the rust) of EX1 are listed in Table 1.

<Comparative Examples 1 and 2 (CE1 and CE2)>

[0035] The procedures and conditions for treating the rusted steel wires of Comparative Examples 1 and 2 were similar to those of Example 1 except for the first electrolyte solution that was used. The first electrolyte solution of Comparative Example 1 was sodium citrate solution. The first electrolyte solution of Comparative Example 2 was sodium hydroxide solution. The conditions for the first electrolytic treatment and the examination results of CE1 and CE2 are listed in Table 1.

Table 1

		EX1	CE1	CE2
1^{st} electrolytic treatment	1st electrolyte solution	Sodium tartrate solution	Sodium citrate solution	Sodium hydroxide solution
	molar concentration(M)	0.5	0.5	0.5
	pH	7.8	8.5	12.5
	temperature(°C)	31	31	31
	current density(A/dm^2)	40	40	40
degree of rust removal		A	D	D
appearance of the treated steel		bright & smooth	many holes on the surface	many holes on the surface

[0036] As shown in Table 1, Example 1 exhibits a greater ability in removing the rust from the rusted steel wire as compared to Comparative Examples 1 and 2.

<Examples 2 to 4 (EX2 to EX4)>

[0037] The procedures and conditions for treating the rusted steel wires of Examples 2 to 4 were similar to those of Example 1 except for the current density that was applied. The current densities applied in Examples 2 to 4 were 60, 80, 100 A/dm^2, respectively.

[0038] After the first electrolytic treatment, the composition of the rust taken from the surface of the rusted steel wire for each of Examples 2 to 4 was examined. The surface of the treated steel wire for each of Examples 2 to 4 was examined by scanning electron microscope and energy dispersive spectroscopy (SEM/EDS). The examination results are listed in Table 2 and Figs. 2 to 4.

[0039] After the examination, the treated steel wire was placed into an ultrasonic oscillator for oscillation for 60 seconds, followed by brushing with a cloth (Manufactured by 3M company, catalog no.: 8501) to obtain the surface-treated steel wire of each of Examples 2 to 4. The surface-treated steel wire of each of Examples 2 to 4 was examined. The treatment conditions and the examination results of EX2 to EX4 are listed in Table 2.

<Comparative Example 3 (CE3)>

[0040] A rusted steel wire (purchased from Walsin company, catalog no.: SS316. having a diameter of 5.5 mm and a length of 50 mm), having a layer of rust with a thickness of 20μm, was prepared. Comparative Example 3 differs from Example 1 in that no treatment was conducted for the rusted steel wire of Comparative Example 3. The composition of the rust of the rusted steel wire was examined. The surface of the rusted steel wire was examined by SEM/EDS. The examination results are listed in Table 2 and Fig.5.

Table 2

		EX2	EX3	EX4	CE3
1st electrolytic treatment	1st electrolyte solution	Sodium tartrate solution			untreated
	molar concentration (M)	0.5			
	pH	7.8~8			
	temperature (°C)	31			
	current density (A/dm^2)	60	80	100	
composition of the rust (wt%)	O	5.44	5.59	5.19	48.4
	Cr	22.03	21.82	22.43	3.58
	Mn	1.78	2.91	2.03	1.49
	Fe	63.44	62.72	63.44	40.65
	Ni	7.31	6.96	6.91	3.88
degree of rust removal		C	B	B	none
appearance of the treated steel	SEM image [before oscillation]	Fig.2	Fig.3	Fig.4	Fig.5
	Visually observed [after oscillation]	bright	Smooth bright	Smooth bright	-

[0041] As shown in Figs. 2 to 4, when the applied current density was greater than or equal to 60 A/dm^2, apparent cracks were formed in the rust of the rusted steel wire. As shown in Table 2, the content of oxygen was drastically reduced from 48.4 wt% (CE3) to 5.44wt% (EX2) when the applied current density was raised to 60 A/dm^2.

<Examples 5 to 11 (EX5 to EX11) and Comparative Example 4 (CE4)>

[0042] The procedures and conditions of treating the rusted steel wires of Examples 5 to 11 and Comparative Example 4 were similar to those of Example 1 except for the molar concentration of the first electrolyte solution, the temperature, and the current density that was applied. The surface-treated steel wire of each of Examples 5 to 11 and Comparative Example 4 was examined.

[0043] The treatment conditions and the examination results of EX5 to EX11 and CE4 are listed in Table 3.

Table 3

	1st electrolytic treatment					degree of rust removal	appearance of the treated steel
	1st electrolytic solution	molar concentration (M)	pH	temperature (°C)	current density (A/dm^2)		
EX5	Sodium tartrate solution	0.8	7.8~8	31	80	B	bright& smooth
EX6	Sodium tartrate solution	1.0	7.8~8	31	80	B	bright& smooth
EX7	Sodium tartrate solution	0.8	7.8~8	30	80	B	bright& smooth
EX8	Sodium tartrate solution	0.8	7.8~8	40	80	B	bright& smooth
EX9	Sodium tartrate solution	0.8	7.8~8	50	80	B	bright& smooth
EX10	Sodium tartrate solution	0.8	7.8~8	60	80	A	bright& smooth
EX11	Sodium tartrate solution	0.8	7.8~8	70	80	A	bright& smooth
CE4	Sodium tartrate solution	0.2	7.8~8	31	80	D	bright& smooth

[0044] As shown in Table 3, the degree of rust removal of Examples 5 to 11 can meet requirements of the steel industries, and the surface-treated steel wire of each of Examples 5 to 11 has a smooth and bright surface.

<Examples 12 to 17 (EX12 to EX17)>

[0045] The procedures and conditions of treating the rusted steel wires of Examples 12 to 17 were similar to those of Example 2 except for the material of the rusted steel wire and the current density. The surface-treated steel wire was examined for Examples 12 to 17.

[0046] The treatment conditions and the examination results of EX12 to EX17 are listed in Table 4 and are shown in Fig. 6.

Table 4

		EX12	EX13	EX14	EX15	EX16	EX17
1st electrolytic treatment	rusted steel	300 series	SS316	A286	625	high-carbon steel	Carbon steel
	1st electrolyte solution	Sodium tartrate solution					
	molar concentration (M)	0.5					
	pH	7.8 to 8					
	Temperature (°C)	31					
	current density (A/dm^2)	20					
appearance of the treated steel		bright smooth	bright smooth	bright smooth	bright smooth	bright smooth	bright smooth

[0047] As shown in Table 4 and Fig. 6, the method of the present invention is also effective in treating rusted steel wires that are made from materials different from SS316.

<Example 18(EX18)>

[0048] The procedures and conditions for treating the rusted stainless steel wire of Example 18 were similar to those of Example 1 except that, after the first electrolytic treatment and before the oscillation and the brushing, the rusted steel was subjectedto a second electrolytic treatment.

[0049] In the second electrolytic treatment, the rusted steel wire was placed in a second electrolytic bath of a 0.5M trisodium phosphate solution (pH 13) to serve as the anode. A titanium plate was used as the cathode. A power supply was electrically connected to the cathode and the anode. The second electrolytic treatment was conducted by applying a current with a current density 40A/dm^2 across the second electrolytic bath under a temperature 31°C for 60 seconds. The surface-treated steel wire was examined.

[0050] The treatment conditions and the examination results of EX18 are listed in Table 5.

<Comparative Examples 5 and 6(CE5 and CE6)>

[0051] The procedures and conditions for treating the rusted steel wire of Comparative Examples 5 and 6 were similar to those of Example 18 except for the first electrolyte solution that was used. The first electrolyte solution of Comparative Example 5 was sodium citrate solution. The first electrolyte solution of Comparative Example 6 was sodium hydroxide solution. The surface-treated steel wires of Comparative Examples 5 and 6 were examined. The treatment conditions and the examination results of CE5 and CE6 are listed in Table 5.

Table 5

		EX18	CE5	CE6
1st electrolytic treatment	1st electrolyte solution	sodium tartrate solution	Sodium citrate solution	sodium hydroxide solution
	molar concentration(M)	0.5	0.5	0.5
	pH	7.8	8.5	12.5
	temperature(°C)	31	31	31
	current density(A/dm²)	40	40	40
2nd electrolytic treatment	2nd electrolyte solution	trisodium phosphate	trisodium phosphate	trisodium phosphate
	molar concentration(M)	0.5	0.5	0.5
	pH	13	13	13
	temperature(°C)	31	31	31
	current density(A/dm²)	40	40	40
degree of rust removal		A	D	D
appearance of the treated steel		bright & smooth	many holes on the surface	many holes on the surface

[0052] As shown in Table 5, Example 18, which uses the sodium tartrate solution as the first electrolyte solution, exhibits a greater degree of rust removal and obtains a more smooth and bright appearance as compared to Comparative Examples 5 and 6.

<Examples 19 to 22 and Comparative Example 7(EX19 to EX22 and CE7)>

[0053] The procedures and conditions for treating the rusted steel wires of Examples 19 to 22 and Comparative Example 7 were similar to those of Example 18 except for the concentration of the sodium tartrate solution and the current density applied across the first electrolytic bath. The current density applied in the first electrolytic treatment of each of Examples 19 to 22 and Comparative Example 7 was 80 A/dm^2. The concentrations of the sodium tartrate solution for Examples 19 to 22 and Comparative Example 7 were 0.4, 0.6, 0.8, 1.0, and 0.2M, respectively. The surface-treated steel wire of each of Examples 19 to 22 and Comparative Example 7 was examined. The treatment conditions and the examination results of EX19 to EX22 and Comparative Example 7 are listed in Table 6.

Table 6

		EX19	EX20	EX21	EX22	CE7
1st electrolytic treatment	1st electrolyte solution	Sodium tartrate solution				
	molar concentration(M)	0.4	0.6	0.8	1.0	0.2
	pH	7.8~8				
	temperature(°C)	31				
	current density(A/dm^2)	80				
2nd electrolytic treatment	2nd electrolyte solution	trisodium phosphate solution				
	molar concentration(M)	0.5				
	pH	13				
	temperature(°C)	31				
	current density (A/dm^2)	40				
degree of rust removal		B	B	A	A	C
appearance of the treated steel		bright smooth	bright smooth	bright smooth	bright smooth	-

[0054] As shown in Table 6, EX19 to EX22 exhibit a greater degree of rust removal and obtain a more smooth and bright appearance as compared to Comparative Example 7.

<Examples 23 to 36 and Comparative Example 8 (EX23 to EX36 and CE8)>

[0055] The procedures and conditions for treating the rusted steel wire of Example 24 were similar to those of Example 21 except for the second alkaline electrolyte solution was a mixture of 0.5M trisodium phosphate solution and 500ml 0.5M sodium citrate solution (mixed at a molar ratio of 1:1, the mixture having a pH of about 8).

[0056] The procedures and conditions for treating the rusted steel wires of Examples 23 and 25 to 27 were similar to those of Example 24 except for the current density applied in the second electrolytic treatment. The current densities applied in the second electrolytic treatment for Examples 23 and 25 to 27 were 20, 60, 80, and 100 A/dm^2, respectively.

[0057] The procedures and conditions for treating the rusted steel wires of Examples 28 to 31 were similar to those of Example 24 except for the molar concentration of the trisodium phosphate solution used in the mixture.

[0058] The procedures and conditions for treating the rusted steel wires of Examples 32 to 36 were similar to those of Example 24 except for the temperature under which the second electrolytic treatment was conducted. The second electrolytic treatment of Examples 32 to 36 were conducted under 30, 40, 50, 60, and 70°C, respectively.

[0059] The procedures and conditions for treating the rusted steel wire of Comparative Example 8 were similar to those of Example 24 except that the second alkaline electrolyte solution was prepared by dissolving 125g sodium chloride and 10g sodium hydroxide in 500ml water.

[0060] The treatment conditions and the examination results of EX23 to EX36 and Comparative Example 8 are listed in Table 7.

Table 7

		EX23	EX24	EX25	EX26	EX27	EX28	EX29	EX30	EX31
1st electrolytic treatment	1st electrolyte solution	sodium tartrate solution								
	molar concentration(M)	0.8								
	pH	7.8 to 8								
	temperature(°C)	31								
	current density(A/dm²)	80								
2nd electrolytic treatment	2nd electrolyte solution	mixture of trisodium phosphate solution and sodium citrate solution								
	molar concentration of trisodium phosphate solution (M)	0.5	0.5	0.5	0.5	0.5	0.2	0.3	0.4	0.6
	pH	8	8	8	8	8	8.4	8.3	8.1	7.9
	temperature(°C)	31	31	31	31	31	31	31	31	31
	current density(A/dm²)	20	40	60	80	100	80	80	80	80
degree of rust removal		C	B	B	A	B	C	B	B	A
Surface appearance of the treated steel		rough mist	rough mist	rough mist	bright mist	rough mist	coarse mist	rough mist	rough mist	bright mist

Table 7 (continued)

		EX32	EX33	EX34	EX35	EX36	CE8
1st electrolytic treatment	1st electrolyte solution	Sodium tartrate solution					
	molar concentration(M)	0.8					
	pH	7.8 to 8					
	temperature(°C)	31					
	current density(A/dm^2)	80					
2nd electrolytic treatment	2nd electrolyte solution	mixture of trisodium phosphate solution and sodium citrate solution					an aqueous solution containing sodium chloride and sodium hydroxide (0.5M)
	molar concentration of trisodium phosphate solution (M)	0.5	0.5	0.5	0.5	0.5	-
	pH	8	8	8	8	8	12
	temperature(°C)	30	40	50	60	70	31
	Current density(A/dm^2)	80	80	80	80	80	40
degree of rust removal		B	B	B	A	A	D
Surface appearance of the treated steel		rough mist	rough mist	rough mist	bright mist	bright mist	many holes on the surface

[0061] As shown in Table 7, Examples 24 to 36 which include the first and second electrolytic treatments, exhibit a greater ability in removing the rust from the rusted steel wire as compared to the Comparative Example 8.

[0062] It is noted that Examples 35 and 36, which were conducted under a temperature greater than or equal to 60°C in the second electrolytic treatment, exhibit greater efficiency in rust removal than Examples 32 to 34.

[0063] In conclusion, by treating the rusted steel in the first electrolytic bath of the first alkaline electrolyte solution that contains tartrate in the method of the present invention, the aforesaid generation of holes in the surface of the steel and formation of the heavy ions in the acidic electrolyte solution may be eliminated.

Claims

1. A method for removing rust from a rusted steel, **characterized by**:

   (a) subjecting the rusted steel to a first electrolytic treatment in a first electrolytic bath of a first alkaline electrolyte solution that contains tartrate, the tartrate in the first alkaline electrolyte solution having a molar concentration equal to or greater than 0.4M, the rusted steel serving as an anode in the first electrolytic bath, the first electrolytic treatment being conducted by applying a current with a current density equal to or greater than 10 A/dm^2 across the first electrolytic bath; and
   (b) applying a mechanical force to the rusted steel after step (a) so as to remove rust from the rusted steel.

2. The method of claim 1, **characterized in that** the tartrate is selected from the group consisting of sodiumtartrate, potassium tartrate, sodiumpotassium tartrate, and combinations thereof.

3. The method of claim 2, **characterized in that** the tartrate in the first alkaline electrolyte solution is sodium tartrate.

4. The method of claim 1, **characterized in that** the first alkaline electrolyte solution has a pH ranging from 7 to 8.5.

5. The method of claim 1, **characterized in that** the first electrolytic treatment is conducted by applying a current with a current density ranging from 20 to 100 A/dm^2 across the first electrolytic bath.

6. The method of claim 1, **characterized in that** the first electrolytic treatment in step (a) is conducted under a temperature ranging from 30 to 70°C.

7. The method of claim 1, **characterized in that** the tartrate in the first alkaline electrolyte solution has a molar concentration ranging from 0.8 to 1.0M.

8. The method of claim 1, **characterized in that** the mechanical force is applied to the rusted steel by brushing, wiping, ultrasonic vibration, or combinations thereof.

9. The method of claim 1, further **characterized by** subjecting the rusted steel to a second electrolytic treatment in a second electrolytic bath of a second alkaline electrolyte solution that contains trisodium phosphate after step (a) and before step (b), the rusted steel serving as an anode in the second electrolytic bath.

10. The method of claim 9, **characterized in that** the second alkaline electrolyte solution further contains a metal chelating agent.

11. The method of claim 10, **characterized in that** the metal chelating agent is selected from the group consisting of citric acid, sodium chloride and the combination thereof.

12. The method of claim 9, **characterized in that** the second electrolytic treatment is conducted by applying a current with a current density ranging from 20 to 160 A/dm^2 across the second electrolytic bath.

13. The method of claim 9, **characterized in that** the second electrolytic treatment is conducted under a temperature ranging from 30 to 70°C.

14. The method of claim 9, **characterized in that** the trisodium phosphate in the second alkaline electrolyte solution has a molar concentration ranging from 0.2 to 0.6M.

15. The method of claim 1, **characterized in that** the first alkaline electrolyte solution further contains polyethylene glycol.

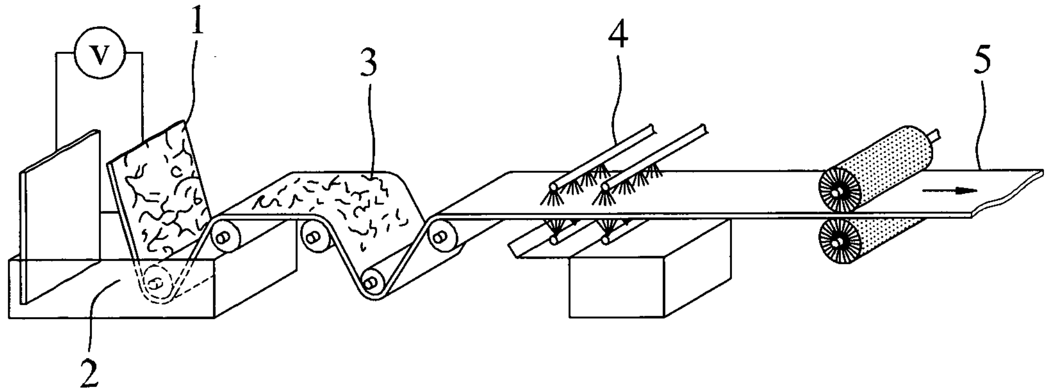

FIG.1

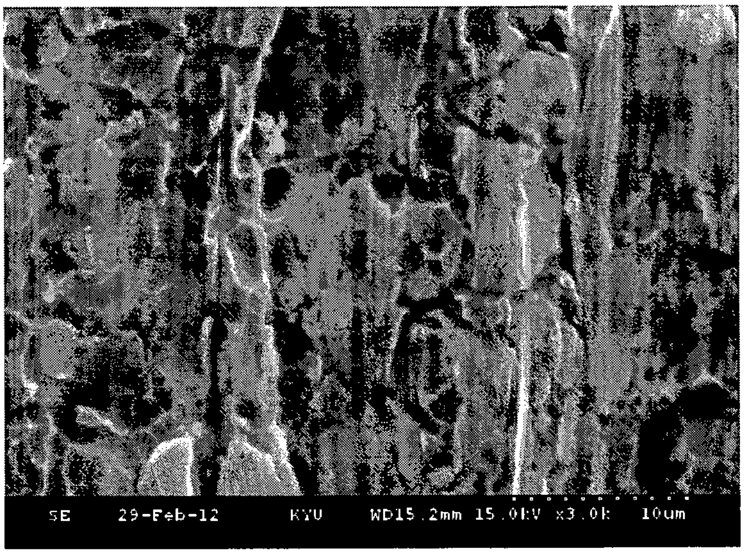

FIG.2

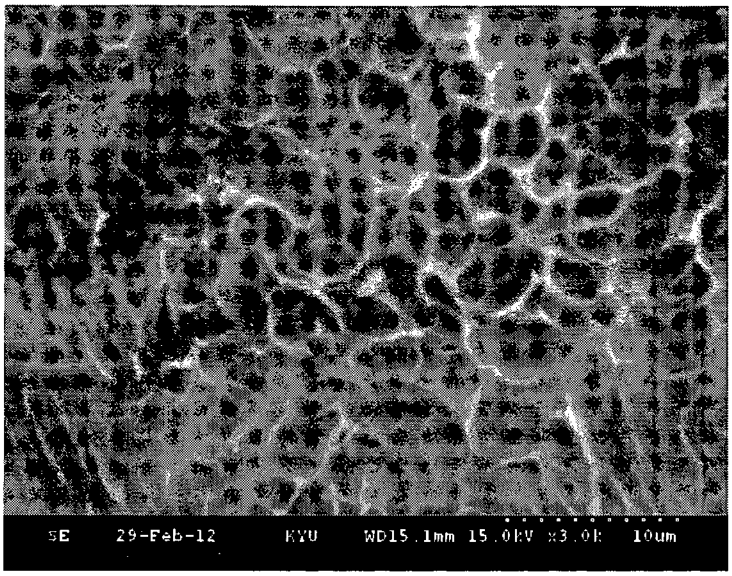
SE 29-Feb-12 KYU WD15.1mm 15.0kV x3.0k 10um

FIG.3

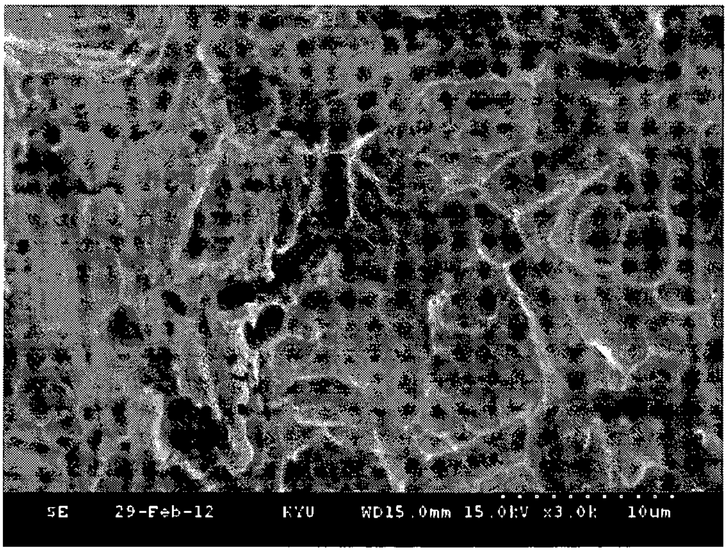
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FIG.4

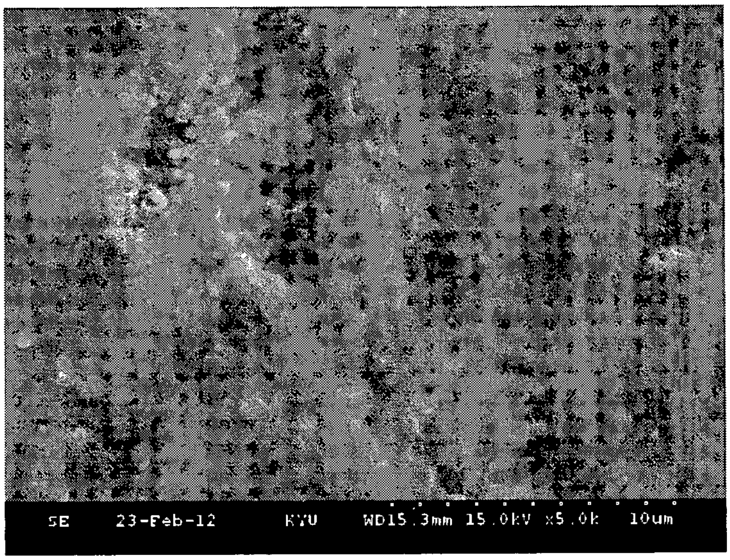

FIG.5

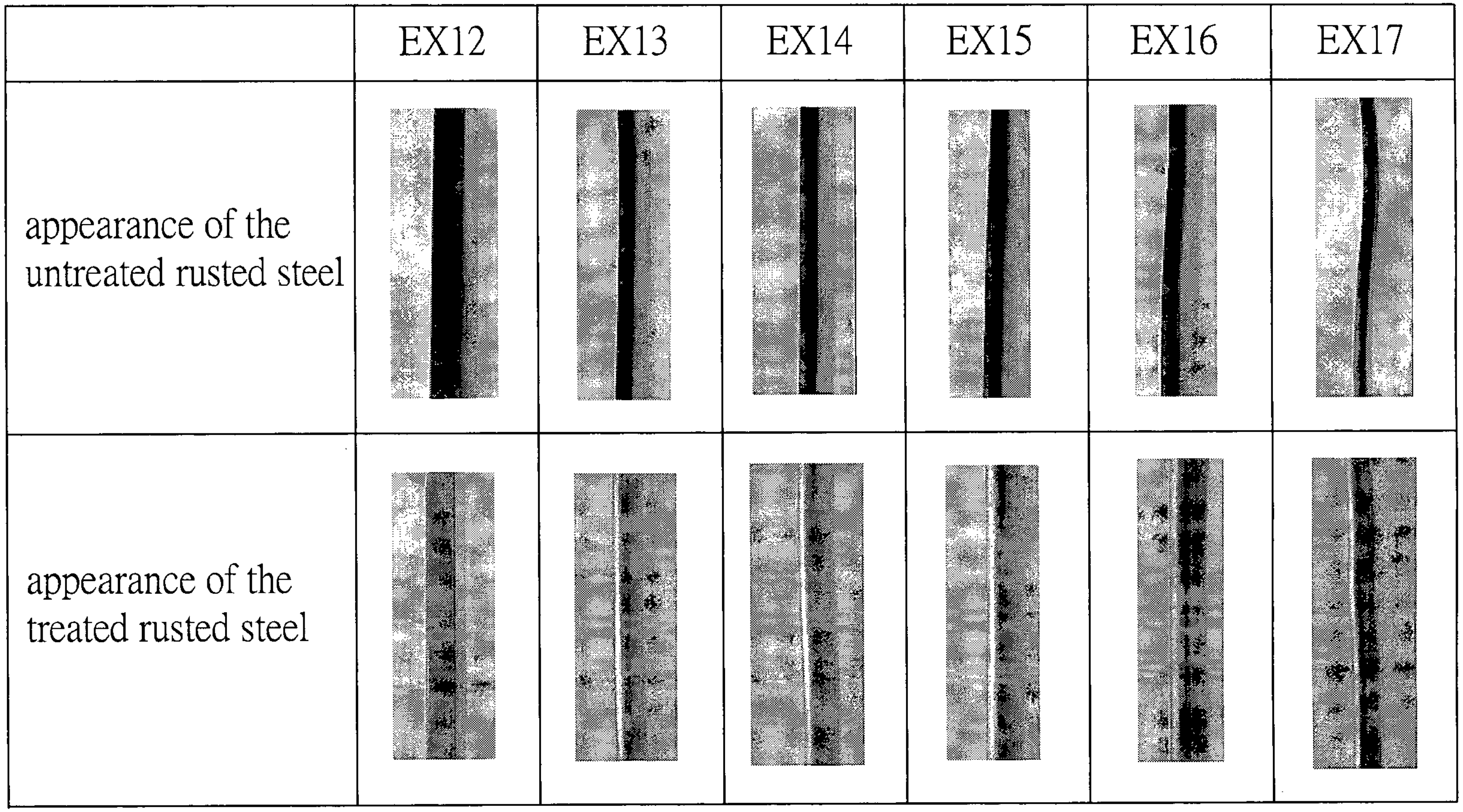
EX12
EX13
EX14
EX15
EX16
EX17
appearance of the untreated rusted steel
appearance of the treated rusted steel

FIG.6

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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