

[54] METHOD FOR PRODUCING A KILLED STEEL WIRE ROD

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[58] Field of Search 148/12 B, 12.3

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[57] ABSTRACT

A method for producing high tensile strength steel wire rods and bars having a basic composition comprising;

C	0.02 to 0.20%
Si	0.03 to 0.90%
Mn	1.00 to 1.85%

together with one or more selected from the group consisting of

Nb	≦ 0.05%	Zr	≦ 0.30%
V	≦ 0.08%	Cr	≦ 0.40%
Ti	≦ 0.25%	B	≦ 0.005%

with the balance being the iron and unavoidable impurities, which comprises heating a steel having the above composition at a temperature not lower than 1,150°C, conducting an intermediate rolling and/or finish rolling at a temperature between 700° and 1,050°C, controlling the cooling rate from the end of the hot rolling to a coiling to 40° to 350°C/sec., and controlling the cooling rate from the coiling to gathering to 1° to 15°C/sec. to obtain hot rolled steel wire rods and bars having excellent workability and spot weldability and having a tensile strength not lower than 50 kg/mm² and a reduction of area not lower than 50 percent.

4 Claims, 6 Drawing Figures

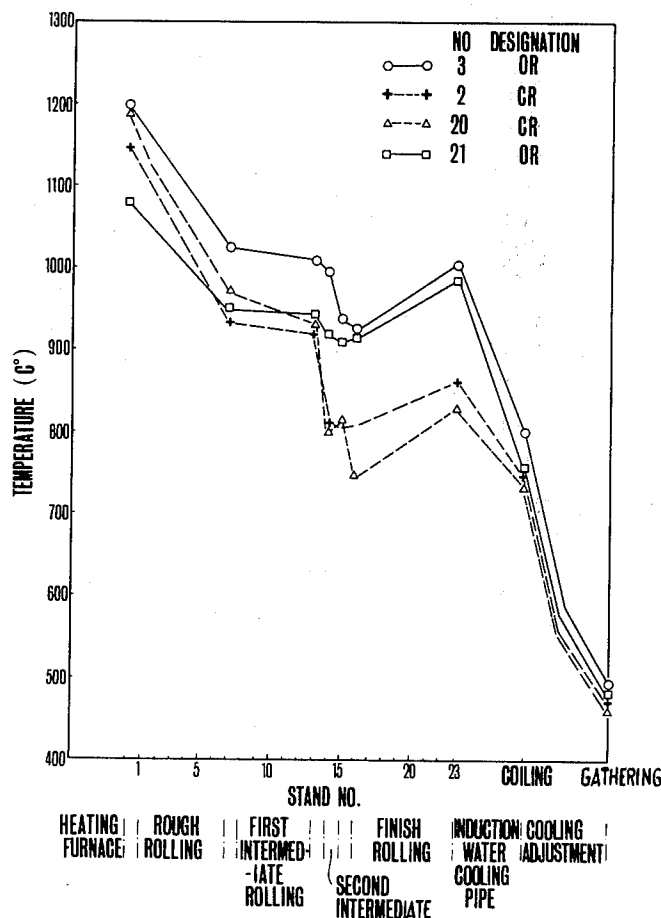


FIG. 1

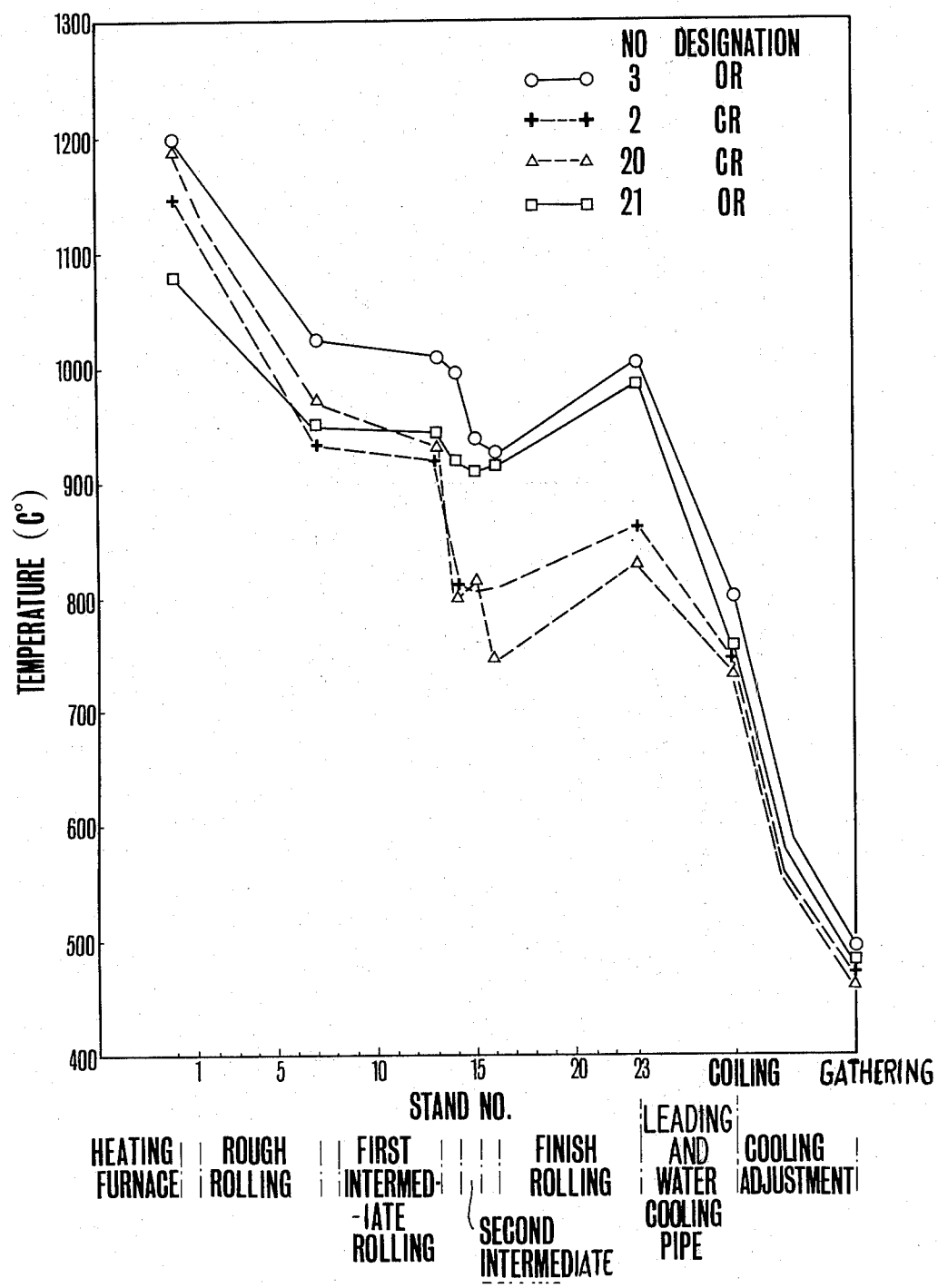
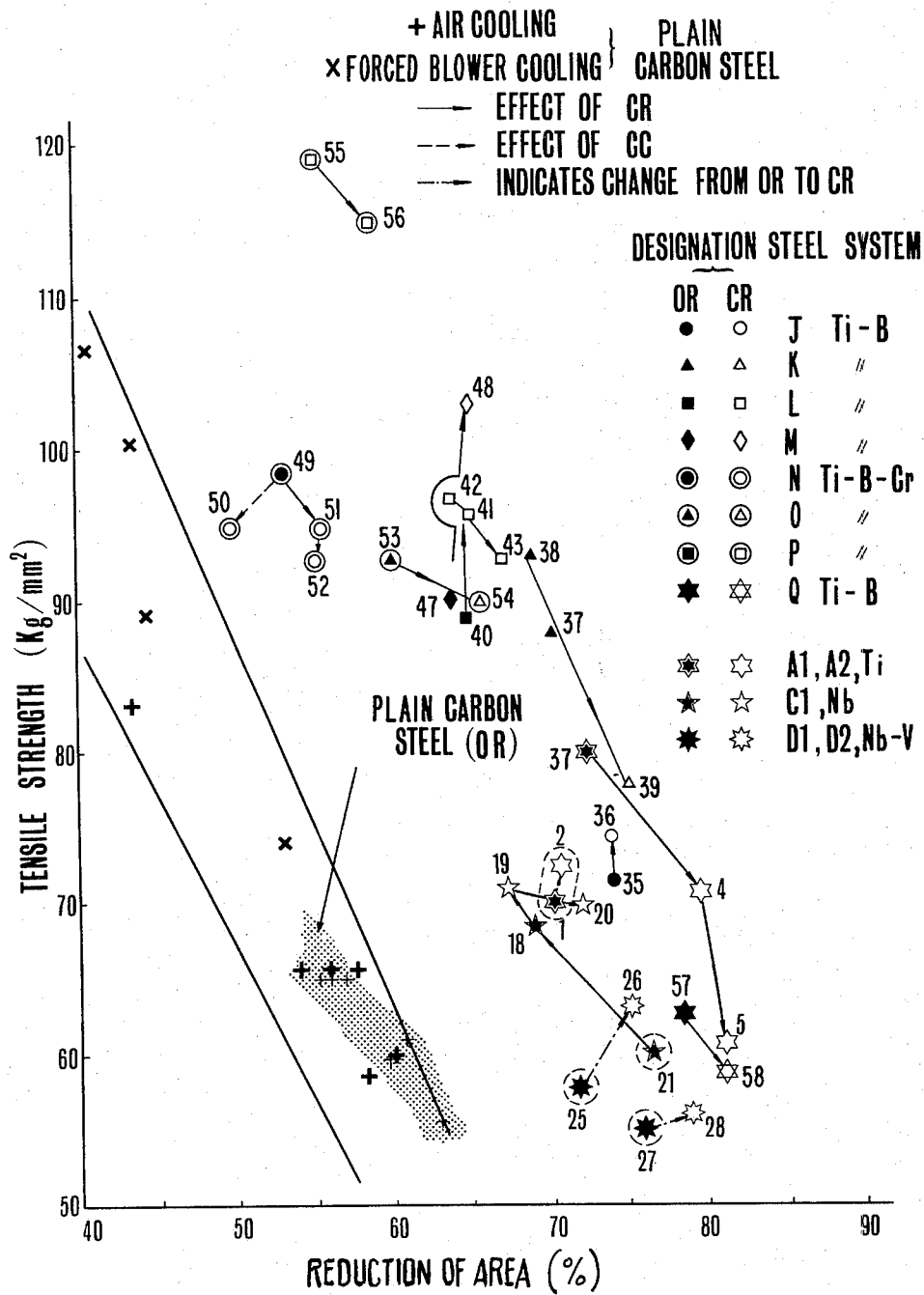


FIG. 2



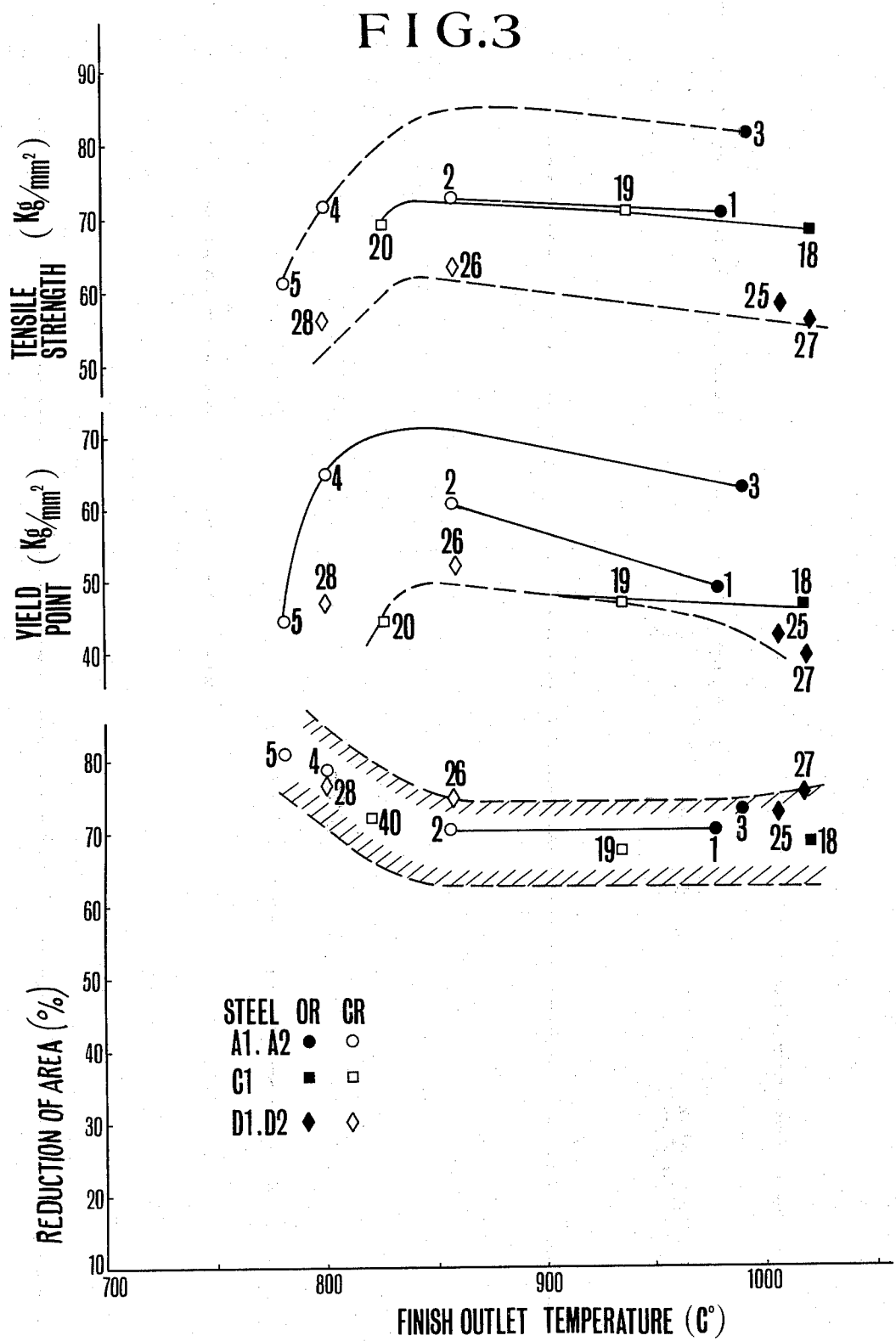
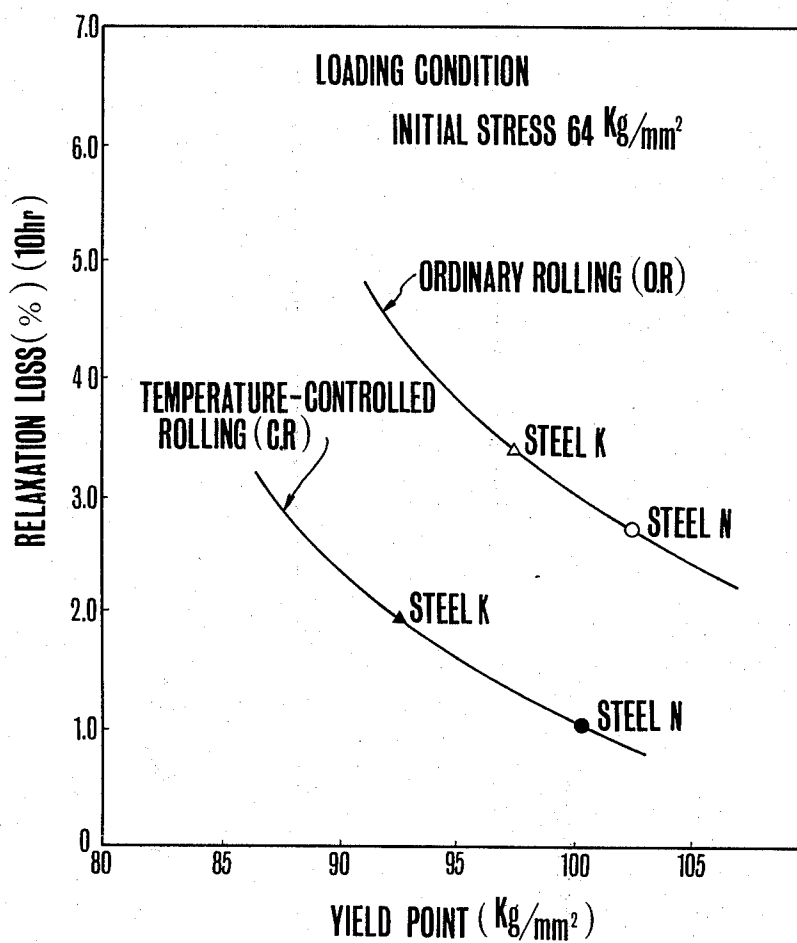
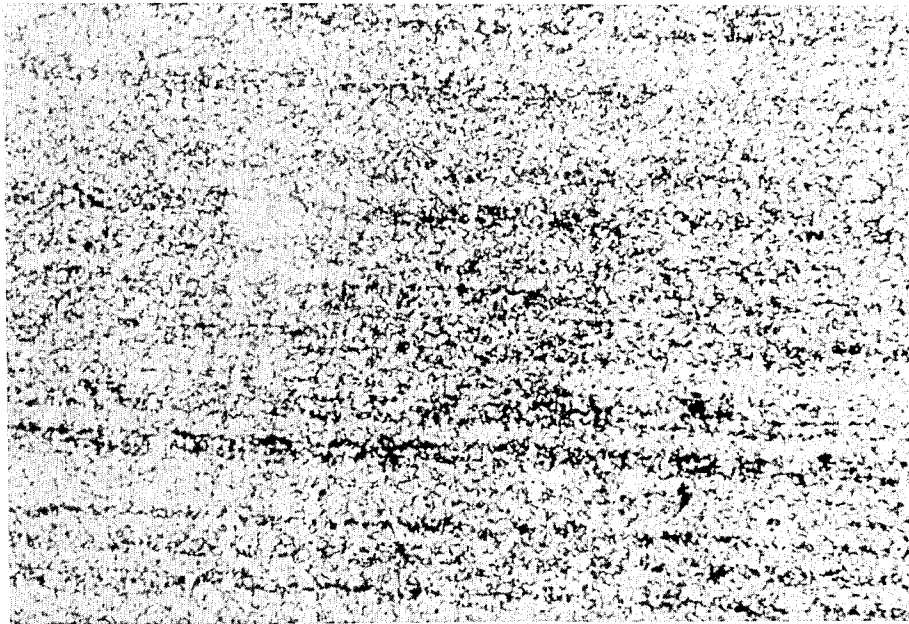


FIG. 4

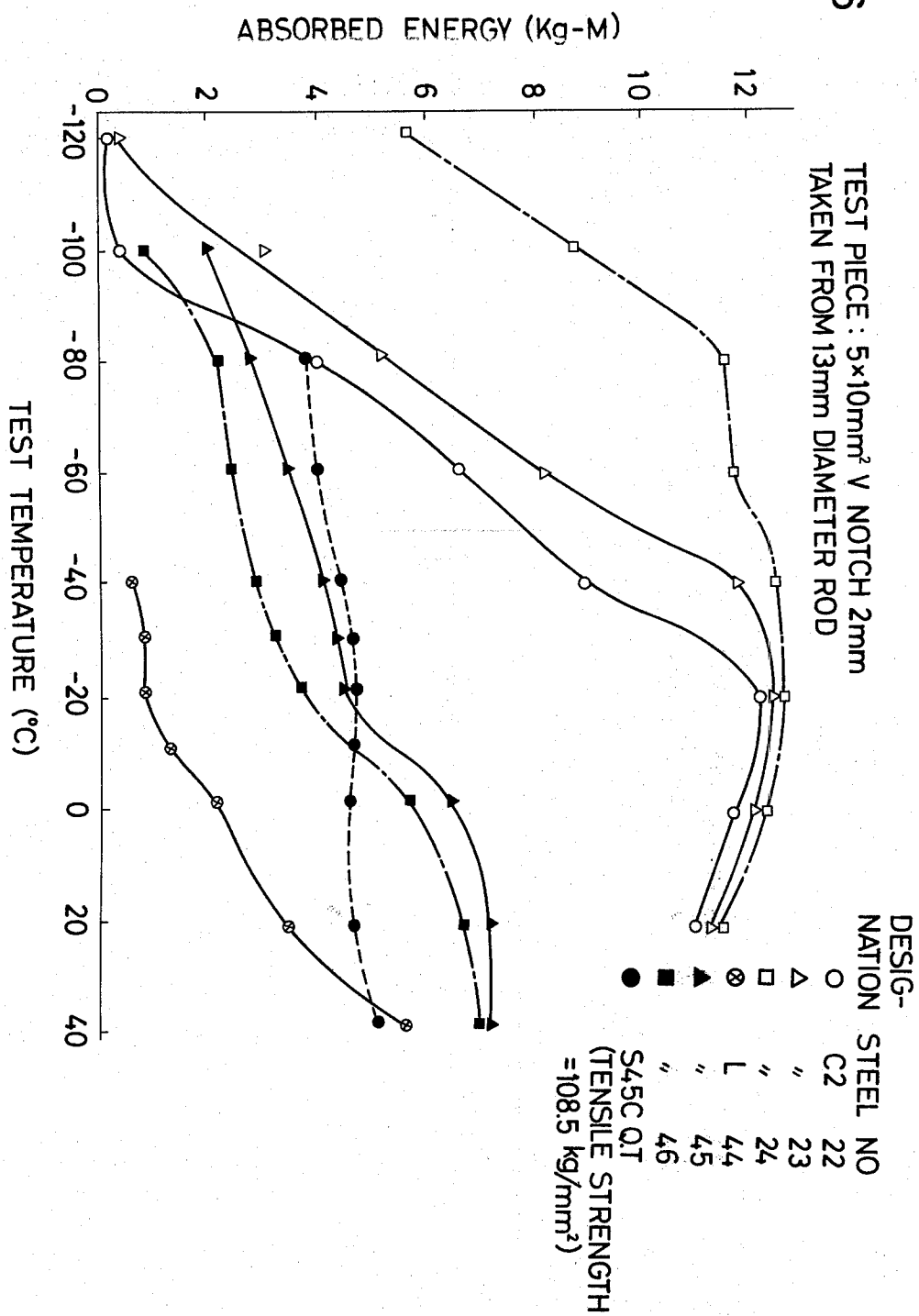




(x200)

FIG.5

F/G.6



METHOD FOR PRODUCING A KILLED STEEL WIRE ROD

The present invention relates to a method for producing a killed steel wire rod (including bar) having a tensile strength of 50 kg/mm² to 110 kg/mm² as hot rolled and having excellent workability especially cold-working cold-forging and drawability and spot weldability. Descriptions will be made for steel wire rods and bars all together.

Up to now, various trials have been made and proposed for development of a steel wire rod having high strength and excellent toughness as hot rolled. However, strength is generally incompatible with toughness and weldability, and a steel material having both high strength and excellent toughness is hard to obtain by an ordinary rolling. Meanwhile a low carbon steel wire rod as rolled shows a tensile strength of 30 to 45 kg/mm², and a high-carbon steel wire rod having 70 to 110 kg/mm² tensile strength is poor in workability and weldability. Proposals have been made for improvement of the as-rolled structure of steel materials as for means for improving these incompatible properties. Among these proposals in the field of a high-carbon steel wire rod, the development of technics of obtaining a sorbide structure having excellent wire-drawability by adjustment of the cooling rate after hot rolling is very important for the production technics for steel wire rods. In case of a low-carbon steel material, addition of alloying elements is essential for increasing the strength, and various trials have been made such that elements such as Si, Mn and Cr are added for improving hardenability, and special elements such as Nb, Ti and V are utilized so as to improve both strength and toughness. However, it has never been proposed or tried to control the cooling of a low-carbon alloy steel wire rod containing the above elements after hot rolling. Much less, it has never been tried to control the rolling temperature in addition so to develop a steel wire rod of good structure having desirable workability.

One of the objects of the present invention is to provide a method for producing a high-strength steel wire rod having a structure of good workability by controlling the temperature of the rolled steel material and also controlling the cooling rate after the finish rolling, and the steel material obtained by the present invention is useful for high-strength bolts, PC wire, metal networks, umbrella ribs, spring washers and springs.

The steel wire rod according to the present invention shows both high strength and excellent toughness, so that it is possible to obtain a product having a similar or better quality than that of a conventional product obtained by a secondary working (mainly of heat treatment) even when the secondary working of the wire rod is considerably omitted. This gives very significant advantages. For example, in case of producing high-strength bolts of the 80 kg/mm² class, the conventional practice is as follows. A high-carbon steel wire rod, such as a plain carbon steel containing 0.45 percent C is subjected to cold wire drawing to a required size, then to a spheroidizing annealing so as to facilitate cold-forgeability to skin-pass working to heading and threading works into bolt shape, to water or oil quenching and lastly to tempering to obtain 80 to 110 kg/mm² strength.

Whereas, in case of the wire rod according to the present invention, the wire rod as hot rolled is sub-

jected only to slight skin-pass drawing into a required size, and then to heading and threading works, thereby a bolt having 80 to 100 kg/mm² of tensile strength without any defect can be obtained, and heat treatments such as spheroidizing annealing, quenching and tempering can be omitted and thus a high level of economy is assured.

Further, when the present invention is applied to production of PC wires (prestressed concrete wires) it is sufficient that the wire rod of the present invention is subjected only to slight skin-pass drawing and shape working including indent work for application is prestressed concrete products for example, and thus the patenting heat treatment which is conventionally done can be omitted. Yet a wire having high tensile strength and very excellent spot weldability can be obtained.

Detailed descriptions will be made on the method of the present invention.

First, regarding the chemical composition of the wire rod according to the present invention, it contains as basic elements 0.02 to 0.20 percent C, 0.03 to 0.90 percent Si and 1.00 to 1.85 percent Mn together with one or more of not more than 0.05 percent Nb, not more than 0.08 percent V, not more than 0.25 percent Ti, not more than 0.30 percent Zr, not more than 0.005 percent B and not more than 0.40 percent Cr, and contains Al in an amount as contained in an ordinary killed-steel with the balance being iron and unavoidable impurities.

The lower limit of 0.002 percent for carbon has been set for the reason that if the carbon content is less than 0.02 percent strength is lowered and desired results can not be obtained, while if the carbon content is beyond 0.20 percent workability and spot weldability lower and thus the upper limit set at 0.20 percent.

Si is a deoxidizing element and also is effective to increase strength by solid solution hardening. For this purpose it is added up to 0.90 percent, beyond which the workability lowers and the addition is uneconomical. The lower limit is set at 0.03 percent which is necessary for deoxidation.

Mn is an element effective to improve hardenability and contributes to facilitate the bainite hardening during cooling after the finish rolling and to convert and refine a bainite structure of the steel matrix, and to improve toughness. The lower limit of Mn is set at 1.00 percent because below this limit the above effects can not be obtained and the upper limit is set at 1.85 percent from the consideration for minimizing adverse effect by the manganese segregation as well as economy.

Nb, V, Ti and Zr, as described hereinafter, are added for the purpose of forming their carbides and nitrides and precipitating them finely during the rolling to suppress recrystallization of austenite grains of the wire rod during the hot rolling so as to refine the ferrite-pearlite or bainite structure produced during the cooling step, as well as for the purpose of increasing strength by precipitating the carbides and nitrides in a super-fine condition. The carbides and nitrides of these elements must be dissolved in solid solution into the steel matrix during the billet heating prior to the rolling of the wire rod and for this purpose, it is necessary to heat the billet at a temperature higher than 1150°C. The upper limits of these elements are set in view of the contents of C and N in the steel and from the economical point.

Cr is added in a small amount for improving hardenability, but as shown in the examples Cr needs not be added in case of a wire rod of small diameter. However, it is desirable to add Cr in an amount not more than 0.40 percent in case of a wire rod of diameter more than about 8 mm. The upper limit of 0.40 percent in this case is set from the reason that Cr addition beyond this limit will not produce any remarkable effect and result only in uneconomy.

B is also added for the purpose of improving hardenability, and its addition is defined to the minimum amount necessary for this purpose.

Ti is necessary to attain fully the effect of B, but Ti is added in the present invention for attaining precipitation hardening by precipitation of fine titanium carbide and nitride, increasing strength through refinement of the grains and improving weldability. The upper limit of Ti is set at 0.25 percent from the limitation in the heating temperature prior to the wire rod rolling as well as from the economical point.

Also in the present invention, it is desirable to maintain Ceq not higher than 0.55% so as to assure excellent spot weldability.

Next, descriptions will be made below on the rolling method of the present invention.

In general, the billet heating temperature for the wire rod rolling is lower than that for the rolling of other products, and is usually between 1,050° and 1,150°C. However, in the present invention, the billet heating temperature should be not lower than 1150°C, preferably not lower than 1200°C in order to assure complete solid solution of the precipitates so as to fully attain the precipitation hardening due to the carbides and nitrides of Nb, V, Ti, Zr and B.

In the present invention the rolling temperature is controlled as under.

In case of a wire rod rolling, a cooling device is not generally used during the rolling and the rolled material is cooled gradually by a small amount of cooling water used to cool the rolls, but in the step of finish rolling, the temperature of the rolled material is raised by the heat of plastic working due to increased rolling speed. (This ordinary rolling method is referred to as OR hereinafter). One of the features of the present invention lies in that the temperature of the steel material during the rolling is controlled by a suitable cooling device. (This method is referred to as CR hereinafter). In this case, the cooling device must have a cooling capacity large enough to cool the steel to a prescribed temperature in a short time because the rolling speed is high, and must be capable to adjust to cooling in association with a thermometer.

The present invention will be described in more details referring to the attached drawings.

FIG. 1 shows the temperature control during the wire rod (8 mm diameter) rolling.

FIG. 2 shows relations between tensile strength and reduction of area of the wire rod as rolled.

FIG. 3 shows relations between the finish outlet temperature and tensile strength, yield point and reduction of area.

FIG. 4 shows similarly relations between yield point and relaxation-loss.

FIG. 5 is a microphotograph ($\times 200$) of the wire rod obtained by the present invention.

FIG. 6 is a graph showing transition curves of impact values.

Now referring to FIG. 1 which shows one embodiment of the continuous rolling apparatus for conducting the controlled rolling according to the present invention, the rolling apparatus includes a rough rolling mill of 7 stands, a first intermediate rolling mill of 6 stands, a second intermediate rolling mill of 2 stands, and a finish rolling mill of 10 stands. In the finish rolling mill, 8 stands are used for production of wire rods of 8 mm diameter, and four stands are used for production of wire rods of 13 mm diameter. The billet size is 115 mm square, and 18 m length. The size of the intermediate products is 24 mm diameter at the stand No. 13 and 20 mm diameter at the stand No. 15.

No. 3 shows the ordinary rolling (OR) in which the heating temperature is set at 1200°C, and the temperature of the rolled material gradually lowers from the rough rolling to the second intermediate rolling and gets about 930°C at the finish inlet, but increases when the rolled material enters the finish rolling mill group and gets a finish temperature of about 1005°C. No. 21 is an example of OR in which the heating temperature is 1085°C, and relatively lower than in No. 3, but almost the same tendencies take place.

No. 2 is an example of the controlled rolling (CR) in which the heating temperature is 1150°C and a cooling device is provided between the first intermediate rolling mill stand group and the second intermediate rolling mill stand group and between the second intermediate rolling mill stand group and the finish rolling mill stand group to adjust the cooling and cool the rolled material to a prescribed temperature. Namely the same procedures are taken until the rolled material passes the first intermediate rolling mill stand group as in case of OR, but after the stand No. 13, the rolled material is cooled to 910°C and rolled by the second intermediate rolling mill, cooled to 810°C after the stand No. 15, enters between the finish rolls and finished at 860°C.

No. 20 is an example of CR in which the temperature of the rolled material is further lowered and the material enters the finished rolling mill stand group at 750°C. The results obtained by the example will be described hereinafter.

For the object of the controlled rolling, the heating temperature should be not lower than 1150°C and is desirably as high as possible. However, in view of limitations, such as, the capacity and structure of a heat furnace, and from the considerations of oxidation and decarburization, the upper limit of the heating temperature is set at 1200°C in this example, because an excessively high temperature is not economical. During the rolling, the above mentioned nitrides and carbides being to precipitate as the temperature lowers but not too much around 1000°C. The austenite phase of the steel material is converted into a deformed structure by the rolling, but immediately recrystallizes because the temperature is high enough and is converted in the worked structure by the next rolling and then recrystallizes. This procedure is repeated at each of the rolling mill stands and in which way the rolling proceeds. The present inventors have studied the above structural changes by investigating the intermediate material having a frozen structure caused by quenching in the course of a rolling, and have found that the carbide and nitride forming elements, such as Nb, delays the recrystallization, and that the recrystallization proceeds immediately at a rolling temperature above about 910°C, but the structure remains as a non-recrystallized phase below 910°C. It is predicted that this temperature var-

ies depending on the rolling speed, namely the passing time between the stands. However, the recrystallization is not caused during the pass time (about 6 seconds) between the stand No. 13 and the stand No. 14 and between the stand No. 15 and the stand No. 16, and the boundary temperature for the recrystallization and the non-recrystallization at the pass time of 6 to 6.5 m/sec. over the stand No. 15 is about 910°C.

It is very important to know what temperature would be this boundary temperature in the finish rolling mill stand group where the rolling speed is larger. Since the rolling time (pass time between stands) is short, namely because the strain rate is high, this boundary temperature is considered to be higher than 910°C, but it is difficult to confirm by experiments whether the recrystallized austenite grains are formed or not. Therefore, the present inventors classified the finish rolled wire rods into the structure in which the worked structure remains and the structure in which the worked structure is not retained through observation of their microstructures, and investigated them in connection with the finish inlet temperature, and found the worked structure is retained when the finish inlet temperature is not higher than 910°C even if the finish temperature is higher than 910°C, and thus discovered that if an adjustment is made in the preceding stands so as to maintain the temperature at the stand No. 16, namely the finish inlet temperature not higher than 910°C, the rolling is regarded to be within the non-recrystallization zone. This technical thought provides means which are applicable to other type of rolling mills. For this purpose, the rolling degrees in this example are shown as under. The rolling degree from the billet of 115 mm square to the intermediate rod of 20 mm diameter (finish inlet) is about 97 percent in the reduction of area, the rolling degree from the intermediate rod of 20 mm diameter to the final product of 8 mm diameter is 84 percent, and the degree from the intermediate rod of 20 mm diameter to the final product of 13 mm diameter is 60 percent, and the pass times in the finish rolling mill stand group is 8 passes for the rolling from the 20 mm diameter to the 8 mm diameter, and 4 passes for the rolling from the 20 mm diameter to the 13 mm diameter.

Descriptions will be made on the method of cooling after the rolling.

The cooling of the wire rod after the finish rolling is divided into two steps; in the first step the surface temperature is cooled by about 100° to 300°C within a few seconds using a leading and cooling device equipped with pipes filled with water as used in the wire rolling mill and the wire rod is coiled to a desired temperature between 850° and 600°C. In the second step, the cooling is done at an adequate rate between 1° and 15°C/sec. using a uniform cooling device such as disclosed in the Japanese patent publications Sho 42-15463 and Sho 42-18894 and the coil is gathered. Thus, the cooling rate after the finish rolling is 2° to 15°C/sec. in average through the first and second steps.

The effects of the above cooling procedure are described hereinafter.

The fine austenite grains are obtained by the controlled rolling as above, and yet in the course of transformation of the austenite into a ferrite-pearlite or bainite structure, the structure gets finer if the cooling rate is increased, thus improving the strength and toughness. Meanwhile the nitrides and carbides precipitated on the dislocation, which is induced in the hot

rolling are coherent with the ferritic matrix and these precipitates harden the ferrite phase remarkably. This precipitation varies depending on the cooling rate and thus it is very important to adjust the cooling rate. Namely, the adjustment of cooling has two distinctive metallurgical significances as above.

Mechanical properties and metallurgical features of the hot rolled wire rod obtained by the above method are explained hereinafter.

Table 1 -(1), (2), and Table 2 show chemical compositions, the relation between the rolling method and temperature and mechanical properties. FIGS. 2 and 3 show, respectively, the relation between tensile strength and reduction of area, between tensile strength and yield point, and between tensile strength and the finish outlet temperature.

All of the steels of the present invention were prepared in LD convertor, but there is no special limitation in the steel-making method.

From the relation between tensile strength and reduction of area shown in FIG. 2, it is understood the steel of the present invention has considerably high strength and high ductility even when rolled by the ordinary rolling method. Namely, the steels No. 1, No. 21, No. 25 and No. 27 show tensile strength of about 55 to 70 kg/mm² and reduction of area of 77 to 70 percent as compared with tensile strength of 55 to 70 kg/mm² and drawability of 65 to 55 percent of an ordinary carbon steel and thus these steels show relatively high reduction of area in comparison with the tensile strength. By comparison of the steel No. 1 with the steel No. 3, and comparison of the steel No. 21 with the steel No. 18, it is clear that the increased heating temperature increases strength even in case of the ordinary rolling material.

In FIG. 2, the CR materials are related by the arrow mark to the OR materials. The steel No. 2 shows only slight effect of CR due to the low heating temperature of 1150°C, but shows improvement of yield point as shown in FIG. 3. Steels No. 4 and No. 5 show remarkable increase of reduction of area, and these steels show remarkable improvement of workability instead of slight increase of yield point (see Table 3). This is due to the fact that the intermediate rolling temperature was set in the order of 700°C and the finish temperature was lowered as shown in Table 1-(2).

Steels No. 19 and No. 20 are examples in which the intermediate rolling temperature was set in the order of 800°C so as to increase strength without lowering reduction of area. The improvement of strength or reduction of area of the steels No. 26 and No. 28 attained by CR is remarkable.

FIG. 3 shows effects of the finish outlet temperature. The finish outlet temperature of the OR material is about 1000°C and that of the CR material is about 950° to 780°C. In case of the CR material, it is clear that tensile strength and yield point lower and reduction of area increases when the finish outlet temperature is below 850°C. It is between about 850° and 950°C that tensile strength and yield point increase while reduction of area does not change. Thus there is difference in the effect by the intermediate rolling temperature between the order of 700°C and the order of 800°C (including 910°C). Similar tendencies are seen even when the rolling size is 13 mm diameter, but it is generally noticed that the heat due to the plastic working varies depending on the reduction amount and the rolling speed in the finish rolling line.

The fact that the steel of the present invention has always higher reduction of area than the ordinary material having the same level of strength is mainly due to the effect by the refinement of the ferrite-pearlite structure as shown in FIG. 5. The ferrite grain size obtained by the controlled rolling temperature is a very fine grain having a grain size number larger than No. 10.

FIG. 6 shows the transition curves of Charpy impact values, and it is clearly shown by this figure that the transition temperature is lowered remarkably by the controlled rolling temperature.

Examples of application of the present invention for hexagonal bolts are shown in Table 3 and Table 4.

The bolt strength is just same or higher than the tensile strength of the wire, and completely no breaking of head was caused in the wedge test (angle: 10°). Also the fatigue limit under pulsating stress is very high.

Further, torque tests were conducted using nuts and the results were that rupture was caused at the thread and thus the bolt strength was satisfactory.

From the above various tests, it has been found the bolts made by the steel wire rod of the present invention have similar or better quality than the conventional quenched-tempered bolts, and thus the excellent quality of the wire rod of the present invention has been confirmed.

Table 1-(1)

Steel Designation	C	Si	Mn	P	S	Al	Cr	Ti	B	N	Ceq*
J	0.03	0.85	1.80	0.026	0.018	0.010	—	0.21	0.0020	0.0041	0.365
K	0.06	0.77	1.58	0.025	0.004	0.004	—	0.20	0.0012	0.0047	0.355
L	0.11	0.78	1.62	0.020	0.009	0.008	—	0.15	0.0025	0.0043	0.413
M	0.15	0.86	1.58	0.024	0.019	0.030	—	0.10	0.0020	0.0045	0.449
N	0.11	0.50	1.59	0.021	0.023	0.025	0.37	0.19	0.0019	0.0049	0.485
O	0.14	0.35	1.54	0.020	0.017	0.028	0.30	0.09	0.0019	0.0048	0.472
P	0.17	0.65	1.52	0.023	0.010	0.010	0.38	0.10	0.0018	0.0049	0.526
Q	0.03	0.25	1.25	0.020	0.008	0.015	—	0.05	0.0015	0.0050	0.250

Table 1-(2)
Chemical Composition (Wt %)

Steel Designation	Serial No.	C	Si	Mn	P	S	Al	Ti	Nb	V
A 1	1	0.06	0.73	1.61	0.021	0.018	0.004	0.19	—	—
	2			"	"					
A 2	3	0.07	0.78	1.52	0.021	0.004	0.004	0.23	—	—
	4			"	"					
	5			"	"					
B	16	0.16	0.86	1.58	0.024	0.019	0.030	0.18	—	—
	17			"	"					
	18	0.13	0.26	1.33	0.024	0.004	0.028	—	0.037	—
C 1	19			"	"					
	20			"	"					
	21			"	"					
	22			1.33	0.024					
C 2	23			"	"					
	24			"	"					
D 1	25	0.13	0.26	1.28	0.023	0.005	0.025	—	0.010	0.020
	26			"	"					
D 2	27	0.11	0.20	1.20	0.025	0.003	0.010	—	0.010	0.020
	28			"	"					
D 3	29	0.12	0.22	1.26	0.024	0.018	0.015	—	0.010	0.025
E	30	0.10	0.25	1.25	0.024	0.015	0.010	0.15	0.015	—
F	31	0.11	0.23	1.24	0.023	0.013	0.015	—	0.015	—
G	32	0.12	0.24	1.26	0.018	0.018	0.018	—	—	0.05
I	34	0.15	0.23	1.28	0.024	0.020	0.018	—	—	—

Steel Designation	Serial No.	Chemical Composition (Wt %)		Rolling Size (mm ϕ)	Rolling Method	Rolling Speed (M/S)	Rolling Temperature (°C)		13 No.
		Zr	N				Heating		
A 1	1	—	0.0047	8	OR	20	1150		1000
	2			"	CR		"		910
A 2	3	—	0.0040	8	OR	20	1195		1020
	4			"	CR		1190		920
	5			"	CR		1190		870
B	16	—	0.0045	8	OR	34	1200		980
	17			"	CR		"		970
	18	—	0.0046	8	OR	34	1200		980
C 1	19			"	CR		"		990
	20			"	CR	20	"		930
	21			"	OR	34	1085		960
	22			13	OR	14	1190		1000
C 2	23			"	CR		"		990
	24			"	CR	10	"		930
D 1	25	—	0.0084	8	OR	20	1170		950
	26			"	CR		1200		850
D 2	27	—	0.0068	8	OR	20	1160		960
	28			"	CR		1200		880
D 3	29	—	0.0045	8	CR	20	1200		880
E	30	—	0.0055	8	CR	20	1200		890
F	31	0.30	0.0050	8	OR	20	1200		885
G	32	—	0.0075	8	CR	20	1200		850
I	34	0.18	0.0050	8	CR	20	1200		885

Serial No.	Rolling Temperature (°C)		Coiling Temperature	Yield	Tensile Properties			Yield
	Finish	Finish			Tensile	Elong-	Reduc-	

Table 1-(1)-continued

Steel Designation	Examples of Steel Composition According to the Present Invention Chemical Composition (Wt %)									
	C	Si	Mn	P	S	Al	Cr	Ti	B	N
	15 No.	Inlet	Outlet	ture (°C)	Point	Strength	ation	tion	Ratio	
					(Kg/mm ²)	(Kg/mm ²)	(%)	of Area (%)		
1	920	920	980	750	48.6	70.0	24.0	69.8	0.69	
2	810	800	860	700	60.3	72.0	26.7	70.4	0.84	
3	930	920	1885	700	62.8	82.1	21.1	72.6	0.76	
4	710	700	800	700	65.0	70.7	25.9	79.0	0.92	
5	720	710	780	700	44.1	61.3	28.6	80.2	0.72	
16	960	930	1010	750	74.0	90.0	15.0	63.5	0.82	
17	890	810	950	700	82.0	103.0	15.5	65.0	0.85	
18	970	970	1020	800	46.2	68.6	23.9	68.9	0.67	
19	910	810	940	"	46.9	71.2	21.9	66.9	0.66	
20	810	750	820	"	45.3	69.8	25.5	71.5	0.69	
21	910	920	985	"	40.0	60.6	27.6	76.6	0.66	
22	940	940	950	"	47.3	60.3	22.7	67.7	0.71	
23	910	800	865	"	47.6	62.6	24.3	74.8	0.76	
24	800	750	840	"	47.9	60.3	25.3	75.2	0.80	
25	950	940	1010	700	42.7	57.7	30.7	71.6	0.74	
26	780	770	860	"	53.6	63.6	26.3	75.2	0.83	
27	960	950	1020	710	39.4	55.3	30.0	75.8	0.71	
28	710	700	800	700	46.7	56.4	29.7	78.7	0.83	
29	710	700	800	700	45.9	56.6	30.0	79.0	0.81	
30	720	715	830	700	48.0	59.0	29.5	76.0	0.81	
31	710	710	805	750	48.5	60.0	27.0	73.0	0.81	
32	780	770	860	700	51.5	62.0	27.0	74.5	0.83	
34	720	710	810	750	49.0	61.0	26.8	74.0	0.80	

Remark: *Ceq = c+1 / 6 Mn+1 / 24 Si+1 / 5 Cr

Remarks OR : Ordinary Rolling

CR : Temperature-Controlled Rolling

Table 2:

Mechanical Properties of Wire Rod As Hot Rolled Rolling Conditions								
Steel Designation	Serial No.	Wire Diameter (mm)	Rolling Method	Rolling Speed	Heating Temperature (°C)	Finish Inlet Temperature (°C)	Finish Outlet Temperature (°C)	Coiling Temperature (°C)
J	35	8 φ	OR	34	1200	945	1020	810
"	36	"	CR	"	1190	810	930	800
K	37	8	OR	20	1210	945	1030	780
"	38	"	"	"	1200	920	1010	650
"	39	"	CR	"	1190	700	810	660
L	40	8	OR	34	1200	945	1005	800
"	41	"	CR	"	"	870	960	"
"	42	"	"	"	"	810	940	"
"	43	"	"	20	"	720	840	"
"	44	13	OR	14	1200	950	970	"
"	45	"	CR	"	"	750	835	"
"	46	"	"	10	"	800	860	"
M	47	8	OR	34	1200	945	1010	750
"	48	"	CR	"	"	810	950	700
N	49	8	OR	34	1180	945	1030	750
"	50	"	CR*	"	"	900	990	800
"	51	"	"	"	"	780	895	"
"	52	"	"	"	"	790	915	820
O	53	8	OR	34	1180	950	1040	750
"	54	"	CR	"	"	770	900	780
P	55	8	OR	34	1200	880	1000	750
"	56	"	"	"	"	760	900	"
Q	57	8	OR	34	1200	940	1030	800
"	58	"	CR	"	"	790	860	"
Tensile Properties								
Steel Designation	Serial No.	Yield Point (Kg/mm ²)	Tensile Strength (Kg/mm ²)	Elongation (%)	Reduction of Area (%)	Yield Ratio		
J	35	58.1	71.5	20.3	74.1	0.81		
"	36	62.7	75.4	19.4	73.8	0.83		
K	37	66.3	87.8	16.1	70.3	0.76		
"	38	76.1	92.6	15.4	69.1	0.82		
"	39	65.5	77.6	23.2	75.3	0.84		
L	40	71.4	89.0	15.5	64.9	0.80		
"	41	79.5	96.4	14.0	64.9	0.83		
"	42	78.4	96.9	14.5	64.2	0.81		
"	43	63.9	92.5	17.8	66.6	0.69		
"	44	66.6	91.0	16.4	61.2	0.73		
"	45	70.9	84.9	14.9	63.7	0.83		
"	46	61.8	85.4	17.5	61.9	0.72		
M	47	74.0	90.0	15.0	63.5	0.82		
"	48	82.0	103.0	15.5	65.0	0.85		

Table 2:-continued

Steel Designation	Serial No.	Mechanical Properties of Wire Rod As Hot Rolled					
		Wire Diameter (mm)	Rolling Method	Rolling Conditions			Coiling Temperature (°C)
				Rolling Speed	Heating Temperature (°C)	Finish Inlet Temperature (°C)	Finish Outlet Temperature (°C)
N	49	77.5	98.5	11.0	53.0		0.79
"	50	73.0	95.0	12.0	50.0		0.77
"	51	82.5	95.1	13.5	56.0		0.87
"	52	80.0	93.0	13.1	55.0		0.86
O	53	73.0	92.5	11.0	60.2		0.79
"	54	78.0	88.5	13.5	65.1		0.88
P	55	93.6	118.5	10.1	55.3		0.79
"	56	93.2	115.3	11.5	58.4		0.81
Q	57	44.5	62.5	20.0	78.0		0.71
"	58	47.2	59.0	22.0	81.0		0.80

Remark:*Air Cooled after Rolling

Table 3

Steel Designation	Serial No.	Wire Diameter (mm ϕ)	Yield Point (kg/mm ²)	Tensile Strength (kg/mm ²)	Elongation (%)	Reduction of Area (%)	Shape	Heading Upsetting ration	Cracking (%)
A1	2	7.0	83	86	10	69	Hexagon	3	0
A2	3	7.0	91	99	8	71	"	3	3
	4	7.0	85	88	9	76	"	3	0.1
D1	26	7.0	76	81	10	71	"	3	0
D2	28	7.0	68	72	12	73	"	3	0

Table 4

Steel Designation	Serial No.	Fatigue Limit under Pulsating Stress (kg/mm ²)	Tensile Strength (kg/mm ²)	Wedge Stress (kg/mm ²)
A1	2	—	88 – 92	87 – 89
A2	3	29.5	103 – 105	102 – 105
A2	4	26.0	89 – 92	89 – 92
D1	26	—	81 – 83	80 – 83
D2	28	21.0	73 – 74	71 – 74

Remarks:Test pieces were extracted at random from about 3000 bolts and test was done on 20 test pieces using nuts.
Fatigue limit:determined after 10⁷ times.

What is claimed is:

1. A method for producing high tensile strength steel wire rods and bars having a basic composition comprising;

- C 0.02 to 0.20 percent
- Si 0.03 to 0.90 percent
- Mn 1.00 to 1.85 percent

together with one or more selected from the group consisting of

- Nb $\leq$ 0.05 percent
- V $\leq$ 0.08 percent
- Ti $\leq$ 0.25 percent
- Zr $\leq$ 0.30 percent
- Cr $\leq$ 0.40 percent
- B $\leq$ 0.005 percent

with the balance being the iron and unavoidable impurities, which comprises heating a steel having above composition at a temperature not lower than 1,150°C, conducting intermediate rolling and/or finish rolling at a temperature between 700° and 1050°C, controlling the cooling rate from finish of the hot rolling to a coil-

ing to 40° to 350°C/sec., and controlling the cooling rate from the coiling to gathering to 1° to 15°C/sec. to obtain hot rolled steel wire rods and bars having excellent workability and spot weldability and having a tensile strength not lower than 50 kg/mm² and a reduction of area not lower than 50 percent.

2. The method according to claim 1, in which the steel wire rods and bars contain one or more of not more than 0.05 percent Nb, not more than 0.08 percent V, not more than 0.25% Ti and not more than 0.30 percent Zr, in addition to the basic composition.

3. The method according to claim 1, in which the steel wire rods and bars contain one or more of not more than 0.25 percent Ti, not more than 0.005 percent B and not more than 0.40 percent Cr in addition to the basic composition.

4. The method according to claim 1 in which the cooling rate from the finish of the hot rolling to the coiling is 150° to 250°C/sec.

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