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(54) **High-performance carbon steel wire.**

(57) A carbon steel wire which contains at least 0.6 % C and which has a boron content of at least 0.0005 % by weight exhibits an improved capacity for processing to high strength levels.

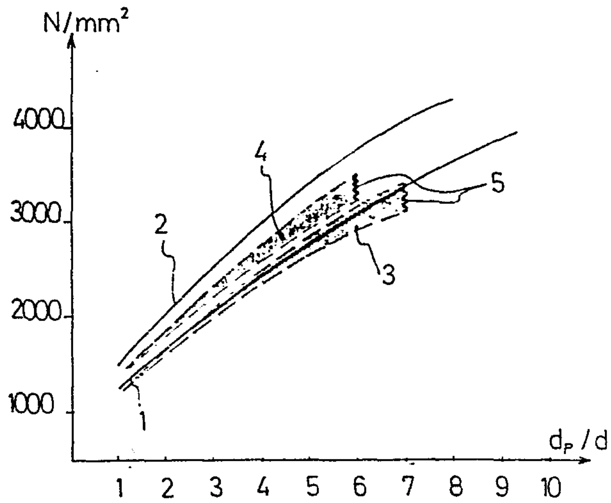

FIG.1

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Croydon Printing Company Ltd.

HIGH-PERFORMANCE CARBON STEEL WIRE

The present invention pertains to the field of drawn carbon steel wire and applications thereof. More in particular the invention relates to a high-strength pearlitic steel wire having a specified composition allowing an improved capacity for effecting large drawing reductions and for obtaining higher than normal levels of useful tensile strength exceeding 2000 Newton per square millimetre. The wire of this invention is suited for demanding applications, such as high-duty ropes cables and springs and more specifically it is intended for reinforcing rubber articles, e.g. steel cord and bead wire for tires, belt cord for rubber belts, hose wire for high-pressure hoses, etc...

Traditionally plain carbon steel wires of sufficient carbon content, inclusive low-alloyed variants thereof, are employed for high-strength applications up to about 2000 N/mm^2. To obtain a predetermined elevated strength level said wires are subjected either to a martensitic quench and tempering treatment or to the combined operation of metallurgical patenting and subsequent cold drawing, the latter being the case of this invention.

At present such drawn pearlitic wires are usually made of plain high-carbon steel having the following general composition (by weight) :

0.50 - 1.00 % C
0.05 - 1.00 % Si
0.20 - 2.00 % Mn
max. 0.035 % P
max. 0.035 % S

the remainder being Fe and unavoidable impurities related to steelmaking practice.

In addition thereto alloyed compositions of said plain carbon steels are sometimes used. These variants may contain a member or members selected from a group consisting of Cr, Ni, Cu, Mo, Co, W, Nb, V, Ti, Al and other elements which can be present in varying amounts depending on the selected member and the alloying purpose for a given application.

In processing and applying drawn carbon steel wire of normal composition for high-performance uses one frequently encounters serious problems related to inconsistent drawing behaviour and wire breaks in production and also to insufficient wire ductility and sudden brittle failure in service.

It is generally acknowlegded by those skilled in the art that these problems, which typically arise in high-tensile applications above 2000 N/mm^2 become even more important as tensile strength is increased, e.g. above 2200 N/mm^2. When approaching the conventional limit of useful strength for a given wire diameter said difficulties may become so severe that wire drawing is impractical or impossible. Thus, in the conventional production of high-tensile wire based on traditional carbon steel compositions, one is confronted with the drawback of poor drawing performance and of frequently unsatisfactory wire properties (e.g. unsufficient ductility in torsion or bending, brittle places, low fatigue life etc.).

Moreover, conventional practice does not permit to further substantially increase the useful strength limit without risk of premature wire embrittlement, which forms a serious obstacle to the extension of wire applicability. Apart from the important role of steel grade and wire processing care in this respect, it is generally ascertained that the practical useful strength limit (according to conventional steel wire practice) is related to wire diameter as follows :

Wire diameter	Average max. Tensile strength
above about 2 mm :	2000 N/mm^2
between 1 and 2 mm :	2200 N/mm^2
between 0.5 and 1 mm :	2400 N/mm^2
below about 0.5 mm :	2500 - 2700 N/mm^2

In the past several proposals have been made with the aim of increasing the useful strength limits as mentioned above and of eliminating the processing difficulties (unexpected breaking, overdrawing and brittle wire,) when producing high-tensile wires.

Among these proposals we notice the demand of tighter compositional tolerances, especially with respect to steel purity (non-metallic inclusions) and residual elements. Hence, for high-performance applications the specification of the residuals sulphur and phosphorus will often be restricted to max. 0.025 %. In addition a careful procedure of acceptance control and steel grade selection has been introduced by many wiremakers.

In spite of these improvements, however, the above mentioned difficulties in the field of high-tensile wire production were not yet fully nor consistently solved.

With the aim of remedying this unsatisfactory situation many steel makers have attempted special and/or additional refining steps to futher improve steel purity and quality and to suppress undesirable impurities down to below the already stringent specifications. On the other hand quite a number of alloying modifications effective in strengthening carbon steel grades have been proposed and tried for the purpose of increasing ultimate wire strength without loss of toughness.

Said measures have proven to be valuable in some singular wire applications, for example rocket wire qualities and other fine wire specialties. Scaling-up to industrial wire practice and mass production, however, has not been an unqualified success, mostly for reasons of unfavorable economics. Indeed, the production of superclean steel requires sophisticated melt refining equipment and more purification steps which lead to a prohibitive cost. Moreover, said extra-improved superior grades are seldom really necessary.

For alloyed carbon steels the price supplementover plain carbon grades, which may widely vary according to type and amount of alloying addition, can be acceptable. In the art of wire making, unfortunately, alloying elements often have undesirable side effects (e.g. prolongement of heat treatment cycles, slower pearlite transformation, more difficult solution of stable carbide formers, etc.) which may seriously affect productivity, especially in the production of fine wires (e.g. for tire cord) necessitating a number of intermediate patenting operations.

The solution offered by the present invention does not possess the disadvantages as explained above, and yet enables to achieve definite and unexcepted improvements over the prior wiremaking art. It thereby fulfils the important object of providing a higher than hitherto achievable useful wire strength (largely exceeding 2000 N/mm^2) in a most efficient and economical way.

Another object of the present invention is to decrease incidence of wire breaks and to suppress the appearance of undesirable brittleness encountered when drawing usual steel wires to high-tensile levels.

Still another important object is to provide a wire having an enhanced deformation capacity, allowing larger than normal total drawing reductions as compared to conventional carbon steel wires.

According to the present invention these and other objects are accomplished by the provision of a drawn steel wire (generally less than 5 mm diameter) having a deformed microstructure consisting of essentially pearlite (obtained by lead patenting or by a similar isothermal transformation process to pearlite and subjected thereafter to a required drawing reduction) and having a useful strength of more than 2000 N/mm^2 , which wire is made from a specified plain carbon steel composition characterized by a micro-alloying addition of boron and containing (in percentage of weight) 0.6 to 1.2 % C, 0 to 1.0 % Mn, 0 to 1.0 % Si, max. 0.035 % P, max. 0.035 % S, 0.0005 to 0.015 % B, the remainder Fe and inevitable impurities.

According to another aspect of the present invention there is provided a drawn pearlitic carbon steel wire having a steel composition as defined above and an elevated tensile strength of not less than following values related to final wire diameter :

$\geqslant$ 2 mm	T.S.	2000 N/mm^2	and preferably	2200 N/mm^2
1 - 2 mm	T.S.	2200	"	2400 N/mm^2
0.5 - 1 mm	T.S.	2400	"	2600 N/mm^2
$\leqslant$0.5 mm	T.S.	2600	"	2800 N/mm^2
$\leqslant$0.3 mm	T.S.	2700	"	3000 N/mm^2

According to an additional aspect thereof said wires are provided with a rubber adherent coating.

According to a preferred feature of the present invention there is provided a drawn carbon steel wire with a tensile stress in excess of 2200 N/mm^2 having a specified composition containing 0.6 to 1.2 % C, 0 to 0.35 % Si, less than 0.60 % Mn, max. 0.008 % N, max. 0.025 % S, max. 0.025 % P and 0.001 to 0.01 % B, the balance Fe and incidental impurities. According to an additional aspect thereof the present invention also provides a carbon steel wire of 0.1 to 0.5 mm diameter having said preferred specified composition and imparted with a tensile strength of at least 2700 N/mm^2, preferably at least 3000 N/mm^2 for diameters of 0.3 mm and below, which wire further contains a rubber adherent brass coating on its surface for the purpose of adequate rubber reinforcement.

Also comprised of the present invention are articles made of pearlitic wires possessing the specified steel composition of this invention and drawn to a high-tensile strength as specified above.

A particular embodiment therein are wire elements and structures for rubber reinforcement, which elements are fabricated from steel wire of the present invention and are covered with a rubber adherent coating, for example brass plated bead wire and steel cord for tires, brassed hose wire, belt cord from brassed or galvanized wires for rubber belts and the like.

Compared to the processing of conventional wires to an elevated strength of more than 2000 N/mm^2 the steel wires of this invention allow larger total drawing reductions without causing a normally encountered increase in wire breaks and without enhanced risk of overdrawing. The latter phenomenon usually gives rise to wire of inconsistent ductility, poor plasticity in torsion and to a significant increase in rejected wire, which deficiencies are largely overcome by the wires of this invention.

An important advantage of the wires produced according to the present invention is their improved residual ductility, which remains satisfactory and reliable even after large total drawing strains. This permits to raise the already elevated useful strength level above the practical safety limits of conventional steel wire.

The accompanying graph of fig. 1 clearly illustrates the main aspects and advantages of the present invention. It shows the comparative strain hardening behaviour of boron alloyed carbon steel wire of this invention and of conventional high-carbon steel wire. Curves (1) and (2) show the relationship between tensile strength (N/mm^2) and deformation degree (expressed as diameter ratio dp/d ; dp = patenting start diameter and d = drawn diameter) of steel wire of this invention, resp. with a standard patented structure and with a extra-fine pearlite structure (2). The shaded bands (3) and (4) refer to cold work hardening by drawing of patented conventional carbon steel wire of resp. 0.65 - 0.70 % C and 0.80 - 0.85 % C. Reference numeral (5) indicates the onset of brittle behaviour when drawing conventional wires. The comparative curves of Fig. 1 clearly demonstrate that the steel wires of this invention are superior in ultimate drawing capacity and in attainable useful tensile strength. Curve 2 further shows that the novel steel wire composition use is apt to enhanced strain-hardening after proper patenting. This additional capacity is not observed in conventional wire processing (owing to less controllable bainite formation when patenting usual steel wire grades to a finest possible pearlite structure).

Returning to the unexpectedly favorable role of boron in the context of high-tensile steel wire production of this invention, we may assume that traditional metallurgical knowledge is unsufficient to give a fully satisfactory explanation.

From said knowledge and related prior art experience it is known that boron increases (quench) hardenability of carbon steel up to a carbon content of about 0.5 - 0.6 %. By adding boron to a given steel grade (usually 0.1 to 0.4 % C) one obtains a larger martensitic hardening depth ; therefore boron is used to substitute a part of otherwise needed (more expensive) alloying elements.

Prior art experience related to wire applications of boron steel include for example U.K. Patent Specification 1.203.779, describing an alloyed carbon steel containing boron as an extra element of a multi-alloying addition of Cr-Ti-Zr + Sn, Sb or As, said alloyed steel resulting in a strength of at least 1000 N/mm^2 in tempered martensite with improved resistance to delayed rupture.

In the French patent 2.058.914 a boron-alloyed carbon steel composition is described for applications of quenched and tempered springs having a martensitic structure and a strength of about 1400 - 1700 N/mm^2.

A German application DE 3312205 describes a boron-treated low-alloyed carbon steel specifying a desired amount of acid soluble boron combined with a small content of Al and Ti, effective in increasing continuous casting yield (steelmaking), whereby said steel composition is intended for prestressed wire of tempered martensitic structure (T.S. of 1500 N/mm^2).

U.S. patent 2.527.731 describes a spring wire drawn from air patented carbon steel wherein the boron addition is intended to allow air patenting of rather thick wires to be substituted for (more expensive) lead patenting without sacrifice of usually obtained mechanical properties (T.S. of about 1800 N/mm^2).

Neither of these prior art proposals presumes the existence of an unexpectedly beneficial boron effect in drawn pearlitic wires of a steel composition as specified by the present invention nor suggests the possibility of taking advantage therefrom to improve drawability and mechanical properties of plain carbon steel wire and to attain a superior tensile class.

From our numerous investigations aimed at raising useful strength levels in hard drawn pearlitic steel wires, and also intended to improve reliability and efficiency of the drawing operation and to control the tendency of cold work brittleness we surprisingly found that boron is remarkably effective when present in a desired range of 0.0005 to 0.015 % (preferably 0.001 to 0.01 %) in a plain high-carbon steel composition of not less than 0.60 % C comprising no other specific alloying additions. According to our findings the use of boron-alloyed high-carbon steel wire allows more particularly to attain larger than normal total diameter reductions and higher than usual strength levels with consistent ductility, and further to avoid undesirable incidental overdrawing at drawing reductions exceeding 90 % and thus to shift incipient embrittlement to larger total deformation degrees. Said enlargement in total drawing range and increase in useful tensile strength levels is most important in high-performance steel wire manufacture and applications thereof, especially in producing fine (brassed) steel wires for steel cord applications, which may be drawn to over 95 - 96 % reduction in area. Thus, the growing demand in industry to increase the useful strength limits and the practical requirements of consistent drawing up to large diameter reductions with minor wire rejections are most advantageously met by the wires of this invention.

Whilst not wishing to be restricted by theoretical explanations (referring for example to a possible extension of the boron hardenability effect in martensitic steel to higher carbon contents and to non-martensitic structures), it is believed that the specific improvements abtainable by adding boron in high-carbon steel wire with a substantially pearlitic structure and subjecting said steel wire to large total plastic deformations by drawing, is probably due to a beneficial synergism of the boron action on pearlite (morphology and structural homogeneity) and on intrinsic steel plasticity (e.g. more favorable inclusion pattern, reduced strain aging embrittlement of nitrogen ...).

An additional surprisingly advantageous effect of boron in steel wire according to the present invention is the capacity to control the patenting heat treatment of said wire in such a way that the as patented tensile strength (P.T.S.) of pearlite can be raised substantially above the maximum level attainable with conventional steel wires of similar carbon content (without risk of forming hard constituents in the pearlite structure). Said maximum strength of undeformed pearlitic steel wire is given by the well-known rule of thumb

$$P.T.S.\ (N/mm^2) = 500 + 1000 \times \%C.$$

With boron steel wire a strength increase of up to more than 100 N/mm^2 above the values of said rule is achievable after controlled isothermal patenting. This advantage could be attributed to an additional refining action of boron on isothermally transformmed pearlite (block size, interlamellar distance) for a given austenite decomposition temperarture and to the suppression of unfavorable reaction by-products (e.g. bainite, divorced pearlite,...) which tend to appear when lowering patenting temperature to critical levels corresponding to finest lamellar morphologies.

The steel wires according to the present invention may be shaped in any appropriate cross-section ranging from a rectangular strip-form (obtainable by flat rolling) to a polygonal shape.

However, a substantially circular cross-section is generally preferred in a majority of end uses. They may be used with advantage in a variety of heavy-duty wire-containing products such as, for example, strands, traction cables, ropes, steel cords and springs.

A particular embodiment of the present invention relates to wire elements formed from steel wires of this invention for use as a rubber reinforcement (such as bead wire and tire beads, steel tire cord, steel belt cord, etc.) and to rubber articles reinforced therewith. For such purposes the wires are provided with a rubber adherable coating, more often a thin brass alloy coating of 0.1 to 0.4 μm thickness, which alloy comprises at least 55 % of copper and preferably 60 to 75 % of copper, the remainder zinc (and sometimes lesser amounts of a ternary alloying element such as cobalt or nickel). When applied in steel cords for tyre reinforcement, the brassed wires for stranding or twisting into cord will generally have a diameter of from 0.10 to 0.40 mm and a tensile class of 2500 - 2800 N/mm^2 and preferably more than 2800 N/mm^2.

The improved residual plasticity of the high tensile wires according to the invention after wire drawing has proved to be particularly beneficial with regard to the cord making operation and to the mechanical properties of rubberized cord in tyre service. As a result, useful tensile strength of said cord wire can be raised above 3000 N/mm^2 without the otherwise occurring difficulties of overdrawing, stranding fractures and inconsistent or unsatisfactory cord properties (e.g. poor cord fatigue life, increased tendency to brittle and stress corrosion cracking).

The following examples will illustrate some important aspects of the present invention into more detail, without limiting the scope of the invention thereto.

In the test results symbol Ø means the wire diamter, T.S. means the tensile strength (stress at rupture in tensile testing), El. means the percent of total elongation, X means the percentage of reduction in area (striction) at tensile rupture, Nb means the number of reverse bends until rupture in the bend test and Nt the number of torsions in the simple torsion test where a length of 100 times the wire diameter is twisted around its axis until it breaks or splits longitudinally.

Example 1

Table 1 shows the chemical composition of a steel wire according to the invention as compared to a normal carbon steel wire. Table 2 shows the mechanical properties of the manufactured wires, in the as hot rolled, resp. as patented condition and after cold drawing.

Table 1 : Chemical composition in weight %

	C	Mn	Si	P	S	B
B-steel	0.64	0.79	0.32	0.018	0.020	0.0055
Conventional steel (C-steel)	0.70	0.55	0.30	0.014	0.021	-

Table 2 : Mechanical properties after wire processing.

	Ø, mm	T.S. N/mm^2	X %	Nt	Nb
B-steel	5.5 as rolled	1080	53.5	n.a.	n.a.
	5.5 patented	1180	47.8	16	8
	2.8 drawn	1765	53.2	34	12
	2.0 drawn	2186	47.4	29	9
	1.5 drawn	2567	45.1	27	11
	1.3 drawn	2769	38.2	24	12
	1.12 drawn	3021	32.0	21	14
C-steel	5.5 as rolled	950	40	15	n.a.
	5.5 patented	1138	39	-	-
	2.8 drawn	1580	34	12	8
	1.5 drawn	2240	36	23	11
	1.3 (*)	2110-2550	23-31	4-21	1-9

(*) frequent drawing breaks, exhaustion of plasticity

The results of drawability tests and mechanical properties demonstrate the superiority of B-steel over normal C-steel, both in work hardening behaviour and in ultimate drawability from rod diameter to smallest as possible intermediate wire size. Residual ductility is clearly better retained in the case of boron steel (% striction or plastic necking of tensile specimens, number of torsions and bends).

Example 2

Boron treated steel wire and a music wire of finest steel quality, both containing about 0.80 % C were predrawn and patented at a wire diameter of 1.50 mm under following conditions : austenitization 930°C - lead bath temperature 560°C. After plating with brass the wires were wet drawn to a final diameter of 0.30 mm.

Table 3 : Chemical composition (weight %)

	C	Mn	Si	P	S	B
B-steel	0.80	0.56	0.28	0.018	0.023	0.0046
music wire	0.83	0.54	0.21	0.009	0.015	-

Table 4 : Mechanical properties of processed wire

	Ø, mm	N/mm²	El	Nt	Nb
B-steel	1.50	1374	8.3	61	10
	0.30	3560	2.4	35	26
music wire	1.50	1325	7.6	56	10
	0.30	3353	2.27	28	22

From table 4 it can be seen that the B-steel wire reaches superior mechanical properties, even slightly better than music wire quality.

Example 3

Boron steel comprising 0.73 % C - 0.9 % Mn - 0.25 % Si - 0.012 % P - 0.022 S and 0.007 B was treated at different lead patenting temperatures and then cold drawn to smaller diameters to evaluate ultimate strengthening behaviour and residual ductility.
Related wire properties are summarized in table 5.

Table 5 : Mechanical properties of patented and drawn boron steel wire

1.50 m				
patented at 580°C				
ø mm	T.S. N/mm^2	Total Elongation %	Number of Torsions n	Number of Bends n
1.50	1278	8.4	-	-
0.30	2847	2.0	55	53
0.25	3115	1.95	51	59
0.20	3547	2.35	21	61
0.155	3760	2.25	17	128

1.0 m				
patented at 525°C				
ø mm	T.S. N/mm^2	Total Elongation %	Number of Torsions n	Number of Bends n
1.0	1469	6.7	-	-
0.30	2745	2.20	54	78
0.25	3078	2.00	45	86
0.20	3450	2.23	56	120
0.155	3937	2.41	25	167

The results show that boron steel is deformable to very high total reductions and gives ultra-high tensile strength levels without complete loss of ductility. Moreover boron steel possesses an unexpected capacity to refine the pearlite microstructure (regulable in combination with an optimum transformation temperature) with virtual absence of undesirable constituents (bainite, divorced pearlite ...) which are unavoidable in conventional steel wire patented at too low a temperature.

In this way the "useful" as patented strength is greatly increased, thereby providing a higher than normal strain hardening rate and exceptional strength values in the finished wire. Compared to boron steel wire of the present invention it would be necessary to raise the carbon content of conventional steel wire with more than 0.15 % in order to obtain (in theory) the same elevated mechanical properties.

In practice however, even the best quality of conventional carbon steel wire tends to become brittle from 3300-3400 N/mm^2 onwards which restricts its fitness for highest-performance applications. Table 6 shows the fatigue limit obtained with hard drawn carbon steel wire of the invention (compare with table 5).

<u>Table 6</u> : Alternate bending fatigue limit σ_n and fatigue to strength ratio σ_n / σ_b of inventive wires

		σ_n , N/mm	σ_n / σ_b
low	0.30 mm from 1.0 mm*	95	0.35
patenting	0.20 mm from 1.0 mm	125	0.36
temperature	0.15 mm from 1.0 mm	140	0.35
high	0.30 mm from 1.50 mm	90	0.31
patenting	0.20 mm from 1.50 mm	105	0.295
temperature	0.10 mm from 1.50 mm	130	0.34

The steel wires in accordance with the invention attain a high fatigue limit and its ratio to the ultimate tensile strength being still more than 0.30 in spite of the elevated strength level, is indicative of the superiority of boron steel wires in very demanding applications.

Example 4

Additionally, the aptitude of steel wires of this invention has been evaluated for steel cord applications and cabling performance. Therefore, cabling loss has been determined on steel cords made of 0.25 mm filaments, resp. from a boron steel with 0.73 % C and from a high-grade usual carbon steel with 0.70 % C and 0.85 % C, of a chemical composition given below.

Chemical composition (%) of B-steel and conventional steel :

	C	Mn	Si	P	S	B	N
B-steel	0.73	0.53	0.23	0.017	0.015	0.0062	0.0032
Conventional	0.70	0.60	0.25	0.019	0.018	-	0.0043
steel	0.85	0.57	0.22	0.014	0.012	-	0.0027

residual elements : Al < 0.01 %
(Cu + Cr + Ni + Mo) < 0.15 %
(Sn + As + Sb) < 0.01 %

Wires 0.25 mm of said steel qualities were cold drawn to a tensile strength class of 3000 to 3200 N/mm^2 .

In table 7 below the proportional loss in tensile strength after stranding (percentage of original wire strength prior to stranding) is summarized for various cord constructions.

Table 7 : Cabling loss in % of original filament strength

	B-steel		Conventional steel	
cord construction	0.25 from 1.5 mm normal patenting	0.25 from 1 mm extra-fine patenting	0.70 % C	0.85 % C
cord 1x7	1 - 3	0 - 2	7 - 10	7 - 5
cord 7x7	5 - 10	4 - 6	10 - 20	9 - 16
cord 7x7x7	14 - 25	10 - 18	20 - 50	17 - 40

From the results it appears that the steel wires of the invention possess a much lesser propensity to strength loss as a result of cord manufacturing, which means that the boron steel wires are more resistant to structural damage given their higher residual ductility in comparison with conventional carbon steel wires.

As can be seen from the examples above the boron steel wire compositions in accordance with the invention exhibit improved drawing performance and later onset of embrittlement. In comparison to conventional high-performance steel wires the wires of the invention can attain a remarkable degree of strain hardening and can be drawn to exceptional strength levels owing to the unexpected beneficial effects of boron on microstructure and ductility.

It will be apparent to those skilled in the art that the advantages of the present invention are readily applicable to minor changes and modifications of the specified steel composition (e.g. the addition of a small amount of grain refiners such as Nb, V, Ti, Zr, Ta ; the addition of desulfurizing agents such as Ce, Ca, ...) without departing from the spirit or scope of the present invention.

CLAIMS

1. A high-strength ferrous wire of suitable cross-sectional shape and dimension having a tensile strength of at least 2000 N/mm² and a deformed microstructure comprised of substantially pearlite, such as e.g. drawn patented steel wire, characterized in that it is composed of boron-microalloyed plain carbon steel containing, in percentage by weight, 0.6 to 1.2 % C, 0 to 1 % Si, 0 to 1 % Mn, 0 to 0.035 %P, 0 to 0.035 % S, 0 to 0.01 % N, 0.0005 to 0.015 B and preferably 0.001 to 0.010 % B, the balance Fe and incidental impurities, which wire thereby attains an effective improvement in ductility properties and deformation capacity (well beyond 2000 N/mm²) over boron-free carbon steel grades.

2. A drawn pearlitic steel wire according to claim 1 having a diameter of up to 2 mm and a tensile strength in excess of 2200 N/mm² and further displaying an enhanced plasticity and torsional ductility compared to boron-free conventional carbon steel wires of similar strength.

3. A drawn pearlitic steel wire according to claim 2 having diameter of from 0.05 to 1 mm and a useful strength of at least 2500 N/mm² , which strength axceeds 2700 N/mm² for wire diameters below 0.5 mm.

4. Improved high-duty wire products such as springs, cables, ropes, steel cords and the like composed of steel wires as specified in any one of claims 1 to 3.

5. Wire elements and steel cords for use in rubber reinforcement composed of steel wires according to claims 2 and 3, wherein said steel wires are covered with a rubber adherable coating.

6. A drawn pearlite steel wire of more than 2200 N/mm^2 in tensile strength having an improved practical processing aptitude to higher than normal useful strength levels in the absence of inconsistent ductility, overdrawing failures or otherwise introduced cold work embrittlement, which wire is basically composed of unalloyed carbon steel containing 0.6 to 1.2 % C, 0 to 0.35 % Si, less than 0.60 % Mn, less than 0.025 % P, less than 0.025 % S, less than 0.008 % N, the remainder Fe and a minor amount inevitable impurities (inclusions and residual elements) not exceeding 0.20 %, which base composition is improved by the addition of boron in a concentration range of from 0.001 to 0.010 % B.

7. A drawn pearlitic steel wire according to claim 6, improved in that the impurity level of residual elements in said high-carbon boron steel is restricted as follows :

Al : max. 0.01 % and preferably max. 0.005 %
(Cu + Cr + Ni + Mo + Co + W + Ti + nb + V + ...) : max. 0.15 % and preferably max. 0.12 %.
Sn + As + Sb + Pb : max. 0.01 %

which composition allows an additional improvement in (fine) wire drawability and the achievement of a wire with superior mechanical properties.

8. A steel wire element for use in rubber reinforcement composed of one or more steel wires of max. 2 mm diameter having a composition and strength as specified in claim 6 or 7, which wires are covered with a rubber adherent coating.

9. A steel cord composed of drawn steel wires according to claim 6 or 7, which wires contain 0.6 - 1 % C and have a diameter of 0.1 to 0.4 mm and a tensile strength of at least 2800 N/mm^2, and preferably not less than 3000 N/mm^2, and are covered with a rubber adherable brass coating before being twisted to a desired cord for use in tire reinforcement.

10. A rubber article reinforced with a steel wire or with a steel wire-containing product according to any one of claims 5 to 9.

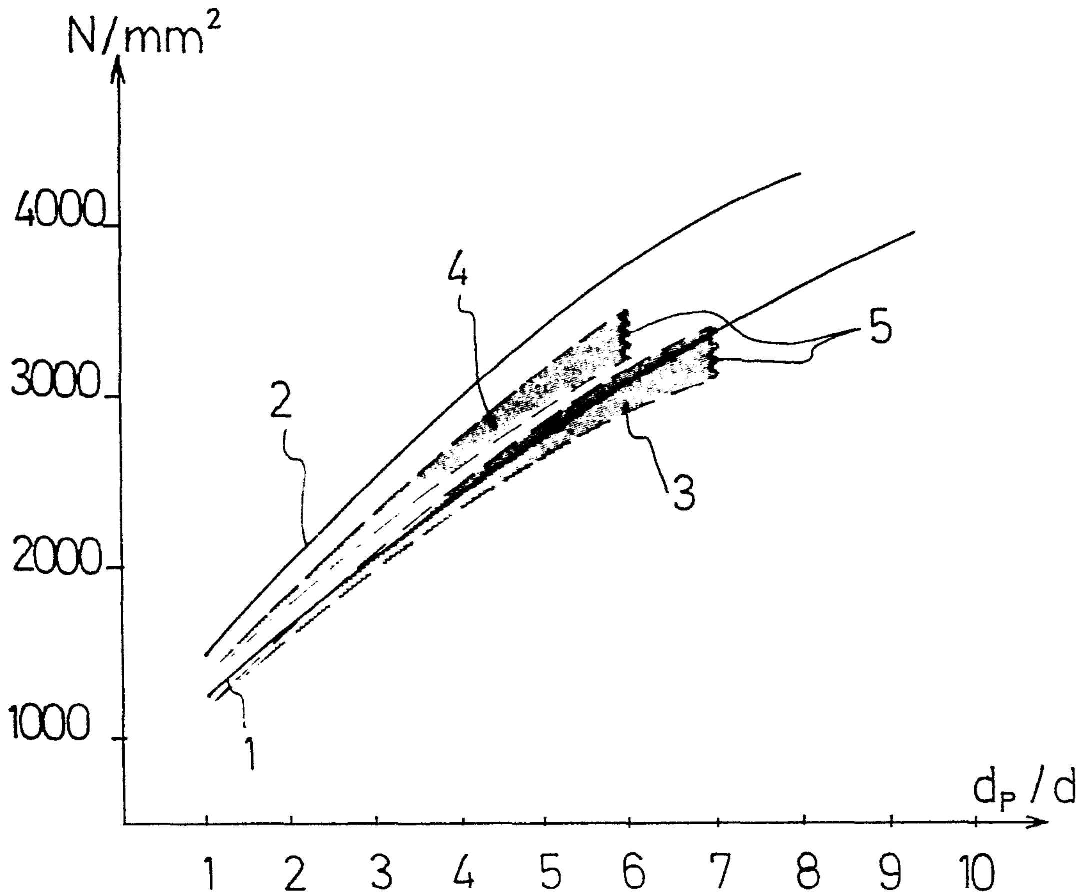

FIG.1

European Patent Office

EUROPEAN SEARCH REPORT

0169587
Application number

EP 85 20 0924

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 4)
D,Y	US-A-2 527 731 (A.F. ILACQUA et al.) * Whole document *	1,4,6	C 22 C 38/00 C 21 D 8/06
Y	PATENTS ABSTRACTS OF JAPAN, vol. 7, no. 155 (C-175)[1300], 7th July 1983; & JP - A - 58 67 828 (SHIN NIPPON SEITETSU K.K.) 22-04-1983	1,4,6	
A,D	GB-A-1 203 779 (YAWATA IRON & STEEL) * Claim 1; page 6, lines 52-62 *	1,6	
A,D	DE-A-3 312 205 (SUMITOMO ELECTRIC) * Claims 1,2; page 8 *	1,6	**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
A,D	FR-A-2 058 914 (CATERPILLAR)	1	C 22 C C 21 D
A	FR-A-2 173 628 (MONSANTO) * Examples *	4,5,8-10	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	08-10-1985	MOLLET G.H.J.

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