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(54) **STEEL WIRE FOR FLEXIBLE CARD CLOTHING**
STAHLDRAHT FÜR FLEXIBLE KARDENGARNITUREN
FIL EN ACIER POUR GARNITURE DE CARDES FLEXIBLE

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Description

Technical Field

[0001] The invention relates to a steel wire for flexible card clothing with improved lifetime. The invention also relates to flexible card clothing with improved lifetime.

Background Art

[0002] Carding is an important process step in the production of cotton yarns. The cotton fibers are fed as flocks into the carding machines. By interaction between card wires on the carding machine, the cotton fibers are disentangled from the tufts and provided in substantially parallel way in a web of fibers. Furthermore, impurities such as neps, wood or leaf particles, seed fragments... are removed from the fibers.

[0003] The most important action for individualizing the cotton fibers on revolving flat carding machines takes place between the metallic card wires on the main cylinder on the one hand; and the revolving flexible card clothing on the other hand. The flexible card clothing of revolving flat cards is known as flexible tops or flats. US6269522 illustrates the operation of the metallic card wire and the flexible card clothing on a carding machine.

[0004] Metallic card wire is produced by punching teeth in a profiled steel wire. A round steel wire is first drawn and then rolled to reduce the cross sectional area of the wire and to create the required cross sectional shape of the profiled steel wire. To enable the drawing and rolling cold deformation processes, the steel wire needs to have an appropriate microstructure. It is known to perform a batch annealing heat treatment on the steel wire in between steps of the cold deformation process. The annealing heat treatment involves spheroidisation of the cementite in the pearlite microstructure to facilitate the cold deformation. After punching the teeth in the profiled steel wire, the tips - and only the tips - of the teeth are first transformed to austenite and then quenched and tempered to provide them with a tempered martensitic microstructure. The other parts of the metallic card wire keeps its pearlitic microstructure. CN105838981A discloses a steel grade that can be used for the production of metallic card wire. WO 2017/059578 discloses a steel wire for carding wire.

[0005] Flexible card clothing comprises small metal hooks which are set into a resilient foundation, mostly comprising multi-ply fabric layers. The hooks are made of steel wires bent into a U shape and provided with a knee. The U-shaped hooks have two sharp tips. The sharpness is important for efficient and effective individualization of cotton fibers.

[0006] The production processes of steel wires used in the production of flexible card clothing differ fundamentally from the production process of steel wires for metallic card clothing and the production process of metallic card clothing. Steel wire for the production of flexible card clothing is produced - via wire drawing and/or wire rolling - while having a pearlite microstructure. At the end of the steel wire production process, the steel wire undergoes a heat treatment process in which the microstructure of the entire steel wire is transformed into tempered martensite. This heat treatment process involves austenization of the whole steel wire, followed by quenching to transform the whole steel wire to martensite and tempering to provide the whole steel wire with the tempered martensite microstructure. The steel wire having a tempered martensite microstructure is used to manufacture the small metal hooks of the flexible card clothing.

[0007] Two major factors affect the lifetime of the flexible card clothing. The cotton fibers - and the impurities in the cotton fibers - exert important abrasive action on the tips of the metal hooks of the flexible card clothing. Loss of sharpness decreases the efficiency of the carding process. The mechanical forces acting on the metal hooks of the flexible card clothing when individualizing the fibers involve a bending fatigue load or even a bending overload. The hooks can permanently deform or even break, again resulting in a lower efficiency of the carding process.

[0008] JP8035125 discloses a steel wire for the production of card clothing. The steel wire has high mechanical strength, toughness, elongation, also wear resistance. The wire is made from a steel alloy composition comprising 0.5 - 0.7 % C by weight, 1.2 - 1.6 % Si by weight, 0.5 - 0.9 % Mn by weight, 0.5 - 1.5 % Cr by weight; and the rest Fe and inevitable impurities. The tensile strength is greater than or equal to 2500 N/mm^2 (2500 MPa) and the elongation at break is more than 5 %.

[0009] The production rate of the revolving flat cards, expressed in mass of fibers processed per unit of time, is steadily increasing, resulting in heavier load - abrasive load as well as bending fatigue load - of the flexible card clothing. Therefore, card clothing is required that provides better resistance to the forces occurring during carding, and hence, has a longer lifetime.

Disclosure of Invention

[0010] An objective of the invention is to provide a steel wire for the production of flexible card clothing with improved lifetime. Another objective of the invention is to provide flexible card clothing with improved lifetime.

[0011] The first aspect of the invention is a steel wire for flexible card clothing. The steel wire has an equivalent diameter between 0.2 and 0.7 mm. With equivalent diameter is meant the diameter of the cross section of a steel wire with circular cross section having the same cross sectional area as the steel wire not necessarily having a circular cross section. The steel wire has a composition comprising between 0.7% and 1.1% by weight carbon; between 0.5% and 1.2% (and preferably less than 1%) by weight manganese; between 0.05% and 0.5% by weight silicon. The steel wire further comprises less than 0.4% by weight chromium; less than 0.05% by weight phosphorus; less than 0.05% by weight sulphur; less than 0.2% by weight copper; and less than 0.2% by weight nickel. The steel wire comprises at least one alloying element, and preferably a plurality of alloying elements. The at least one alloying element - and preferably the plurality of alloying elements - are selected from the group of vanadium, titanium, niobium, tungsten and boron. When the at least one alloying element is selected from the group of vanadium, titanium, niobium and tungsten, the content of the at least one alloying element is between 0.02% and 0.2% by weight. When the at least one alloying element is boron, the content of boron is at least 0.001 % - and preferably more than 0.004% - by weight. The steel wire composition further comprises unavoidable impurities and the remainder being iron. The steel wire has a tempered martensitic microstructure. The microstructure of the steel wire comprises between 1 and 10 % by volume of undissolved carbides. Preferably, the microstructure of the steel wire comprises more than 2% by volume of undissolved carbides. More preferably, the microstructure of the steel wire comprises more than 3% by volume of undissolved carbides. Even more preferably, the microstructure of the steel wire comprises more than 4% by volume of undissolved carbides.

[0012] With undissolved carbides is meant the carbides that have not been dissolved when austenitizing the steel wire. Thus, the austenitizing process to manufacture the steel wire of the invention is an incomplete austenitizing of the steel wire. Undissolved carbides are alternatively known as primary carbides or spheroidized carbides. They are called spheroidized carbides because of their spherical shape. The presence of undissolved carbides can be detected through scanning electron microscopy (SEM), and their amount (volume percentage) can be determined through image analysis on scanning electron microscopic images after the application of an appropriate etching method (e.g. etchant 74 in ASTM E407-2007).

[0013] The steel wire of the invention allows making flexible card clothing with higher lifetime, thanks to the combination of improved resistance against the abrasive forces acting on the tips of the hooks, and the higher resistance against bending fatigue load. The specific microstructure and composition of the steel wire allows that the tips of the hooks of the flexible card clothing can be hardened to high hardness, and thus to high abrasion resistance. The tips can be converted by the hardening treatment into a fine martensitic microstructure (thanks to alloy composition and the fine microstructure of the inventive steel wire) with high carbon content and free from undissolved carbides. Outside the hardened tips - and outside the transition zone that is present because of the tip hardening process - the specific fine tempered martensitic microstructure comprising undissolved carbides provides the improved fatigue resistance (resistance against permanent deformation and even against breakage) of the flexible card clothing. This is achieved as the martensitic microstructure comprises lower carbon content because of the carbon present in the undissolved carbides. Therefore, the card wire surprisingly allows making flexible card clothing combining high fatigue resistance (thanks to a high yield strength Rp0.2) with high abrasion resistance at the tips after hardening, and therefore longer lifetime. The combination of high fatigue resistance with high abrasion resistance of the tips is surprising as these properties are normally inversely correlated to each other.

[0014] Steel wires according to the invention can be made according to the following process:
steel wires are processed into final cross sectional shape and dimensions according to techniques known in the art. After reaching the final cross sectional shape and dimensions, specific heat treatment is performed that provides the steel wire of the invention with the specific microstructure and properties. First, the wire is incompletely austenitized. The incomplete austenitization is realized by controlling the heating temperature (between Ac1 and Ac3), heating time or the running speed of the elongated steel wire. The incomplete austenitization of the specific steel composition - especially the presence of the alloying elements selected from the group of vanadium, titanium, niobium, tungsten and boron - results in the presence of undissolved carbides and a fine microstructure. The austenitization is followed by low temperature quenching (e.g. in oil) and tempering thereby achieving the final microstructure as claimed.

[0015] In preferred embodiments, the cross section of the steel wire is not round. More preferably, the steel wire has a biconvex cross section. With biconvex cross section is meant a convex cross section that is continuously rounded.

[0016] More preferably, the steel wire has a biconvex cross section with ratio of the longest to the shortest calliper diameter at least 1.2, more preferably 1.3. Examples of such biconvex wires are (provided are the longest and the shortest calliper diameter): 0.38 * 0.28 mm; 0.405 * 0.305 mm and 0.43 * 0.33 mm.

[0017] Preferably, the residual austenite of the steel wire is less than 4 % by volume, more preferably less than 3 % by volume; more preferably less than 1%. Such wires are preferred as higher amount of residual austenite could be harmful when converted in the production of the flexible card clothing into untempered martensite, which is a brittle microstructure. The content of residual austenite can be determined by means of X-Ray Diffraction (XRD) or magnetic measurement.

[0018] A preferred steel wire comprises at least 0.001 % by weight of boron; and more preferably less than 0.01% by weight of boron. Boron is one of the alloying elements that can be used to achieve the beneficial technical effects of steel wires according to the invention. It is a specific benefit of boron that it can achieve the beneficial effects with only low amount of boron in the steel wire.

[0019] A preferred steel wire comprises between 0.05 and 0.2% by weight of vanadium; more preferably less than 0.15% by weight of vanadium. Vanadium is one of the alloying elements that can be used in the invention to achieve the beneficial technical effects of steel wires according to the invention.

[0020] Preferably, the tempered martensite grains have a shape with a long length and a short length, wherein the ratio of the long length to the short length is less than 2, more preferably less than 1.5. With long length and short length are meant the longest and shortest distances in a cross section of the wire through the center of gravity of the grain, as can be determined in optical microscopy on longitudinal sections on steel wires.

[0021] In principle in the steel wire of the invention the tempered martensite grains are equiaxial, meaning they do not have a preferential direction. However the presence of inclusions can cause a limited preferential orientation of grains along the longitudinal direction of the wire. However, such preferential orientation is much less than in an end drawn microstructure; and cannot be confused with the microstructure of an end drawn martensitic wire, in which the preferential longitudinal orientation of tempered martensite grains is much more pronounced.

[0022] Preferably, the tempered martensite grains have an average grain size less than 10 μm; more preferably less than 8 μm, even more preferably less than 6 μm. This fine grain size synergistically contributes to the favourable mechanical properties, e.g. a high yield strength resulting in a resistance to permanent deformation of the flexible card clothing and hence a high lifetime of the card clothing made with such steel wire. Grain size of the tempered martensite grains can be measured according to ASTM E112-13. The method is an optical method in which the average is taken from the longest and the smallest dimension of the grain on the picture.

[0023] In preferred embodiments, the steel wire has tensile strength Rm at least 2400 MPa and yield strength Rp0.2 at least 2100 MPa.

[0024] A preferred steel wire has yield strength Rp0.2 at least 2200 MPa, more preferably at least 2250 MPa.

[0025] A preferred steel wire has a ratio of the yield strength Rp0.2 to the tensile strength Rm higher than 90%.

[0026] Preferably, the elongation at break At of the steel wire is more than 3%, more preferably more than 4%.

[0027] A second aspect of the invention is flexible card clothing, comprising hooks and a foundation. The hooks comprise steel wire as in any embodiment of the first aspect of the invention. Preferably, the foundation comprises a number of fabric layers bonded together. The hooks are set into the foundation. Each of the hooks comprises a base section and two legs. The base section is provided parallel with the foundation and at one side of the foundation. The two legs penetrate through the foundation; and each of the two legs has a sharpened tip. Preferably each of the legs is bent, providing a knee.

[0028] Flexible card clothing is made starting from the foundation and steel wire. The first process step is performed on a setting machine. Short length of steel wire is cut and bent into the shape of a hook. The hook is inserted through the foundation. In most occasions, after insertion into the foundation, each leg of the hook is bent into a knee. After setting all hooks in the foundation, the tips are sharpened on a special machine. This sharpening operation involves grinding the sides of the tips and creating the so-called backing off. This way, a sharp tip is provided that is required for efficient carding. Another step is the hardening of the sharpened tips. The hardening process is a heat treatment of the sharpened tips. The heat treatment involves providing a quenched martensitic microstructure to the tips of the wire, thereby creating enhanced abrasion resistance of the tips. Preferably, the martensitic microstructure of the tips is free from undissolved carbides, as the undissolved carbides have been dissolved in the austenitization step of the hardening process of the tips.

[0029] As will be clear from the description of the production process, the basis of the steel wire and the legs outside the region that has been affected by the tip hardening operation maintain the microstructure of the steel wire with which the flexible card clothing is produced.

[0030] In preferred flexible card clothing, the base and at least part of the legs have a tempered martensitic microstructure. The tips have a martensitic microstructure with Vickers hardness number (HV) higher than 800 HV, more preferably higher than 900 HV. Preferably, the martensitic microstructure of the tips is free from undissolved carbides, as the undissolved carbides have been dissolved in the austenitization step of the hardening process of the tips. Preferably, the microstructure of the tips is a quenched martensitic microstructure, more preferably an untempered quenched martensitic microstructure.

Brief Description of Figures in the Drawings

[0031]

Figure 1 shows an example of flexible card clothing.
Figure 2 illustrates the tensile stress - strain curve of a steel wire.
Figure 3 shows an example of a metallic card wire.

Mode(s) for Carrying Out the Invention

[0032] Figure 1 shows an example of flexible card clothing 10 according to the invention. The flexible card clothing comprises hooks 12 and a foundation 14. The foundation typically consists out of a number of layers of woven cotton fabric, bonded together by means of a rubber based adhesive, and a top layer 16 of rubber. The hooks comprise steel wire according to the invention. The hooks are set into the foundation. Each of the hooks comprises a base section 18 and two legs 20. The base section is provided parallel with the foundation and at one side of the foundation. The two legs penetrate through the foundation. The legs are bent, thereby forming a knee 22. Each of the two legs has a sharpened tip 24, by side grinding and by providing a backing off 26 to the tip. The tips are hardened, thereby providing a quenched martensitic microstructure to the tips; whereas the sections of the hooks not affected by the hardening operation of the tips retain the microstructure of the steel wire used to make the flexible card clothing.

[0033] The flexible card clothing according to the invention can interact on a carding machine with metallic card wire. Figure 3 shows an example 300 of such metallic card wire.

[0034] Figure 2 provides information about the way the mechanical properties of the steel wires are described in this document. The mechanical properties are described and tested according to ISO 6892-1:2016. Figure 2 schematically illustrates a stress-strain curve of a steel wire in an uniaxial tensile test. In the X-axis, the strain is provided. The vertical (Y) axis provides the tensile stress (in MPa). The elongation at breakage is represented by At. The tensile strength Rm is the maximum stress. The yield strength Rp0.2 is the stress when crossing the tensile curve with the line through 0.2% strain and parallel with the elastic modulus line.

[0035] In order to illustrate the invention, comparative experiments have been performed. The steel grades of the wire rods used are listed in table 1, providing the percentages by weight of the different elements in the steel grades. Specifics on steel wire, heat treatment conditions, microstructure and mechanical test results are provided in table 2.

[0036] Eight different steel wires have been made in comparative experiments. The steel wires are numbered 1 - 8. Wire numbers 1 and 2 are reference samples, whereas wire numbers 3 - 8 are steel wires according to the invention.

[0037] Reference steel wires 1 and 2 are made from wire rod with steel grade A and B respectively (see table 2; information on the steel grade composition is provided in table 1, the composition being given in percentage by weight). After processing the steel wires 1 and 2 to their final cross sectional shape and dimensions; the wires are subjected to a thermal treatment with conditions as provided in table 2. The austenitization is a complete austenitization. After austenitization, the steel wires are quenched in oil and tempered. Mechanical properties of the steel wires and information on their microstructure is provided in table 2.

[0038] Steel wire number 3 is a steel wire according to the invention made of wire rod C. Steel wire number 4 is a steel wire according to the invention made of wire rod D. Steel wires number 5, 6, 7 and 8 are steel wires according to the invention made of wire rod E. Each of the steel wires 3 - 8 is - after processing the steel wire to its final shape and dimensions - processed in a heat treatment process involving incomplete austenitization. This is clear from the austenitization temperature provided in table 2, which is between Ac1 and Ac3, resulting in undissolved carbides. Austenitization is followed by oil quenching and tempering. Information on the microstructure and the mechanical properties is provided in table 2. The synergistic action of the steel grade (and especially the carbon content and the presence of alloying elements) and the specific fine microstructure comprising undissolved carbides results in excellent mechanical properties of the steel wires numbers 3 - 8. The high yield strength is especially noticed. Steel wires 3 - 8 can be processed into card clothing that has high resistance to fatigue, as the risk of permanent deformation of the hooks of the card clothing is strongly reduced. The tips of the hooks have high abrasion resistance after hardening the tips of the legs of the hooks. The surprising combination of the resistance to fatigue and the abrasion resistance of the tips results in flexible card clothing with high lifetime.

[0039] The amount of residual austenite in the microstructure of steel wire number 3 has been measured by means of XRD and was less than 1% by volume.

[0040] The steel wires of the specific examples all comprise vanadium. However, the beneficial effects of the invention can be achieved by selecting other alloying elements from the group of vanadium, titanium, niobium, tungsten and boron; when at least containing the minimum quantities as claimed. Vanadium, titanium, niobium, and tungsten are alloying elements forming stable carbides that limit austenite grain growth during austenitization and create improved hardenability. Boron on the other hand leads mainly to improved hardenability. These actions are very important towards improvement of lifetime of the tips and of the base of the hooks in flexible card clothing.

Table 1: Wire rod compositions used in the comparative experiments

No.	C%	Mn%	Si%	P%	S%	Cr%	Cu%	Ni%	Al%	V%	B%	Nb%
A	0.663	0.693	0.203	0.009	0.004	0.044	0.040	0.028	-	-	-	-
B	0.678	0.758	0.255	0.007	0.003	0.229	0.016	0.018	0.026	-	-	-

(continued)

No.	C%	Mn%	Si%	P%	S%	Cr%	Cu%	Ni%	Al%	V%	B%	Nb%
C	0.720	0.745	0.190	0.013	0.006	0.105	0.007	0.011	0.002	0.080	-	-
D	0.763	0.709	0.192	0.012	0.004	0.307	0.039	0.026	-	0.119	-	0.061
E	0.827	0.682	0.248	0.010	0.009	0.015	0.013	0.019	0.001	0.076	0.003	-

Table 2: Specifics on steel wires, their heat treatment conditions, microstructure and mechanical test results

Example	1	2	3	4	5	6	7	8
Wire rod (see table 1)	A	B	C	D	E	E	E	E
Equivalent diameter [mm]	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355
Austenitization temperature [°C]	> 850	> 850	790	780	785	785	785	785
Quenching temperature [°C]	< 60	< 60	< 60	< 60	< 60	< 60	< 60	< 60
Tempering temperature [°C]	> 340	> 340	310	310	250	275	300	320
Rm [MPa]	2013	2437	2510	2440	2980	2785	2663	2528
Rp0.2 [MPa]	1815	1910	2225	2242	2209	2183	2208	2315
Rp0.2/Rm [%]	90.2	78.3	88.7	92.5	74.1	78.4	82.9	91.6
At [%]	4.0	5.8	4.5	3.8	7.0	6.9	5.9	3.8
Average martensite grain size [μm]	20	15	< 10	< 10	< 10	< 10	< 10	< 10
Average amount of undissolved carbides [volume%]	< 1	< 1	3.0	3.8	3.9	4.2	4.0	5.0

Claims

1. A steel wire for flexible card clothing,

wherein the steel wire has an equivalent diameter between 0.2 and 0.7 mm;
wherein the steel wire has a composition comprising

0.7% - 1.1 % by weight carbon;
0.5% - 1.2 % by weight manganese;
0.05% - 0.5% by weight silicon;
less than 0.4% by weight chromium;
less than 0.05% by weight phosphorus;
less than 0.05% by weight sulphur;
less than 0.2% by weight copper;
less than 0.2% by weight nickel; and
at least one alloying element with a content of 0.02% - 0.2% by weight and selected from the group consisting of vanadium, titanium, niobium and tungsten, or between 0.001 % by weight and 0.01% by weight of boron,

the steel wire composition further comprises unavoidable impurities and the remainder being iron,
wherein the steel wire has a tempered martensitic microstructure,
wherein the microstructure of the steel wire comprises between 1 and 10 % by volume of undissolved carbides,
wherein the content is measured as defined in the description.

2. Steel wire as in any of the preceding claims, wherein the tempered martensite grains have a shape with a long length and a short length, the ratio of the long length to the short length is less than 2.

3. Steel wire as in any of the preceding claims, wherein the tempered martensite grains have an average grain size less than 10 μm.

4. Steel wire as in any of the preceding claims, wherein the steel wire has tensile strength Rm at least 2400 MPa and yield strength Rp0.2 at least 2100 MPa tested according to ISO 6892-1:2016.

5. Steel wire as in any of the preceding claims, wherein the steel wire has yield strength Rp0.2 at least 2200 MPa tested according to ISO 6892-1:2016.

6. Steel wire as in any of the preceding claims, wherein the ratio of the yield strength Rp0.2 to the tensile strength Rm is higher than 90% tested according to ISO 6892-1:2016.

7. Steel wire as in any of the preceding claims, wherein the elongation at break At is more than 3% tested according to ISO 6892-1:2016.

8. Steel wire as in any of the preceding claims, wherein the steel wire comprises between 0.05 and 0.2% by weight of vanadium.

9. Flexible card clothing, comprising hooks and a foundation,

wherein the hooks comprise steel wire as in any of the preceding claims 1 - 8;
wherein the hooks are set into the foundation,
wherein each of the hooks comprise a base section and two legs,
wherein the base section is provided parallel with the foundation and at one side of the foundation,
wherein the two legs penetrate through the foundation,
wherein each of the two legs has a sharpened tip.

10. Flexible card clothing as in claim 9,

wherein the base and at least part of the legs have a tempered martensitic microstructure,
wherein the tips have a martensitic microstructure with hardness higher than 800 HV, more preferably higher than 900 HV.

11. Flexible card clothing as in claim 10, wherein the microstructure of the tips is free from undissolved carbides.

12. Flexible card clothing as in claims 10 or 11; wherein the microstructure of the tips is a quenched martensitic microstructure.

13. Flexible card clothing as in claim 12, wherein the microstructure of the tips is an untempered quenched martensitic microstructure.

Patentansprüche

1. Stahldraht für eine flexible Kardengarnitur,

wobei der Stahldraht einen Äquivalentdurchmesser zwischen 0,2 und 0,7 mm aufweist;
wobei der Stahldraht eine Zusammensetzung, umfassend

0,7 Gew.-% - 1,1 Gew.-% Kohlenstoff;
0,5 Gew.-% - 1,2 Gew.-% Mangan;
0,05 Gew.-% - 0,5 Gew.-% Silicium;
weniger als 0,4 Gew.-% Chrom;
weniger als 0,05 Gew.-% Phosphor;
weniger als 0,05 Gew.-% Schwefel;

weniger als 0,2 Gew.-% Kupfer;
weniger als 0,2 Gew.-% Nickel; und
mindestens ein Legierungselement mit einem Gehalt von 0,02 Gew.-% - 0,2 Gew.-% und ausgewählt aus der aus Vanadium, Titan, Niob und Wolfram bestehenden Gruppe oder zwischen 0,001 Gew.-% und 0,01 Gew.-% Bor, aufweist,

die Stahldrahtzusammensetzung ferner unvermeidbare Verunreinigungen umfasst und es sich bei dem Rest um Eisen handelt,
wobei der Stahldraht ein Gefüge aus angelassenem Martensit aufweist, wobei das Gefüge des Stahldrahts zwischen 1 und 10 Vol.-% ungelöste Carbide umfasst, wobei der Gehalt wie in der Beschreibung definiert gemessen wird.

2. Stahldraht nach einem der vorhergehenden Ansprüche, wobei die Körner aus angelassenem Martensit eine Form mit einer langen Länge und einer kurzen Länge aufweisen, wobei das Verhältnis der langen Länge zur kurzen Länge weniger als 2 beträgt.

3. Stahldraht nach einem der vorhergehenden Ansprüche, wobei die Körner aus angelassenem Martensit eine durchschnittliche Korngröße von weniger als 10 μm aufweisen.

4. Stahldraht nach einem der vorhergehenden Ansprüche, wobei der Stahldraht bei der Prüfung gemäß ISO 6892-1:2016 eine Zugfestigkeit Rm von mindestens 2400 MPa und eine Dehngrenze Rp0.2 von mindestens 2100 MPa aufweist.

5. Stahldraht nach einem der vorhergehenden Ansprüche, wobei der Stahldraht bei der Prüfung gemäß ISO 6892-1:2016 eine Dehngrenze Rp0.2 von mindestens 2200 MPa aufweist.

6. Stahldraht nach einem der vorhergehenden Ansprüche, wobei das Verhältnis von Dehngrenze Rp0.2 zu Zugfestigkeit Rm bei der Prüfung gemäß ISO 6892-1:2016 mehr als 90 % beträgt.

7. Stahldraht nach einem der vorhergehenden Ansprüche, wobei die Bruchdehnung At bei der Prüfung gemäß ISO 6892-1:2016 mehr als 3 % beträgt.

8. Stahldraht nach einem der vorhergehenden Ansprüche, wobei der Stahldraht zwischen 0,05 und 0,2 Gew.-% Vanadium umfasst.

9. Flexible Kardengarnitur, die Haken und eine Grundlage umfasst,

wobei die Haken Stahldraht nach einem der vorhergehenden Ansprüche 1-8 umfassen;
wobei die Haken in die Grundlage eingelassen sind, wobei jeder der Haken einen Basisabschnitt und zwei Füße umfasst,
wobei der Basisabschnitt parallel zur Grundlage und an einer Seite der Grundlage bereitgestellt wird,
wobei die zwei Füße die Grundlage durchdringen,
wobei jeder der zwei Füße eine angespitzte Spitze aufweist.

10. Flexible Kardengarnitur nach Anspruch 9,

wobei die Basis und wenigstens ein Teil der Füße ein Gefüge aus angelassenem Martensit aufweisen,
wobei die Spitzen ein martensitisches Gefüge mit einer Härte von mehr als 800 HV, weiter bevorzugt mehr als 900 HV, aufweisen.

11. Flexible Kardengarnitur nach Anspruch 10, wobei das Gefüge der Spitzen frei von ungelösten Carbiden ist.

12. Flexible Kardengarnitur nach den Ansprüchen 10 oder 11, wobei es sich bei dem Gefüge der Spitzen um ein abgeschrecktes martensitisches Gefüge handelt.

13. Flexible Kardengarnitur nach Anspruch 12, wobei es sich bei dem Gefüge der Spitzen um ein nichtangelassenes abgeschrecktes martensitisches Gefüge handelt.

Revendications

1. Fil en acier pour garniture de cardes flexible,

   le fil en acier ayant un diamètre équivalent compris entre 0,2 et 0,7 mm ;
   le fil en acier ayant une composition comprenant :

   0,7 % - 1,1 % en poids de carbone ;
   0,5 % - 1,2 % en poids de manganèse ;
   0,05 % - 0,5 % en poids de silicium ;
   moins de 0,4 % en poids de chrome ;
   moins de 0,05 % en poids de phosphore ;
   moins de 0,05 % en poids de soufre ;
   moins de 0,2 % en poids de cuivre ;
   moins de 0,2 % en poids de nickel ; et
   au moins un élément d'alliage avec une teneur de 0,02 % - 0,2 % en poids et choisi dans le groupe constitué par le vanadium, le titane, le niobium et le tungstène, ou entre 0,001 % en poids et 0,01 % en poids de bore,

   la composition du fil en acier comprenant en outre des impuretés inévitables, le reste étant du fer,
   le fil en acier ayant une microstructure martensitique revenue,
   la microstructure du fil en acier comprenant entre 1 et 10 % en volume de carbures non dissous, la teneur étant mesurée comme défini dans la description.

2. Fil en acier selon l'une quelconque des revendications précédentes, les grains de martensite revenue ayant une forme avec une grande longueur et une petite longueur, le rapport entre la grande longueur et la petite longueur étant inférieur à 2.

3. Fil en acier selon l'une quelconque des revendications précédentes, les grains de martensite revenue ayant une taille moyenne de grain inférieure à 10 μm.

4. Fil en acier selon l'une quelconque des revendications précédentes, le fil en acier ayant une résistance à la traction Rm d'au moins 2400 MPa et une limite d'élasticité Rp0.2 d'au moins 2100 MPa testées selon la norme ISO 6892-1:2016.

5. Fil en acier selon l'une quelconque des revendications précédentes, le fil en acier ayant une limite d'élasticité Rp0.2 d'au moins 2200 MPa testée selon la norme ISO 6892-1:2016.

6. Fil en acier selon l'une quelconque des revendications précédentes, le rapport entre la limite d'élasticité Rp0.2 et la résistance à la traction Rm étant supérieur à 90 % testé selon la norme ISO 6892-1:2016.

7. Fil en acier selon l'une quelconque des revendications précédentes, l'allongement à la rupture At étant supérieur à 3 % testé selon la norme ISO 6892-1:2016.

8. Fil en acier selon l'une quelconque des revendications précédentes, le fil en acier comprenant entre 0,05 et 0,2 % en poids de vanadium.

9. Garniture de cardes flexible, comprenant des crochets et une fondation,

   les crochets comprenant du fil en acier selon l'une quelconque des revendications précédentes 1 à 8 ;
   les crochets étant fixés dans la fondation,
   chacun des crochets comprenant une section de base et deux pattes,
   la section de base étant prévue parallèlement à la fondation et sur un côté de la fondation,
   les deux pattes pénétrant à travers la fondation,
   chacune des deux pattes ayant une pointe aiguë.

10. Garniture de cardes flexible selon la revendication 9,

   la base et au moins une partie des pattes ayant une microstructure martensitique revenue, les pointes ayant une microstructure martensitique avec une dureté supérieure à 800 HV, plus préférablement supérieure à 900 HV.

11. Garniture de cardes flexible selon la revendication 10, la microstructure des pointes étant exempte de carbures non dissous.

12. Garniture de cardes flexible selon la revendication 10 ou 11, la microstructure des pointes étant une microstructure martensitique trempée.

13. Garniture de cardes flexible selon la revendication 12, la microstructure des pointes étant une microstructure martensitique trempée non revenue.

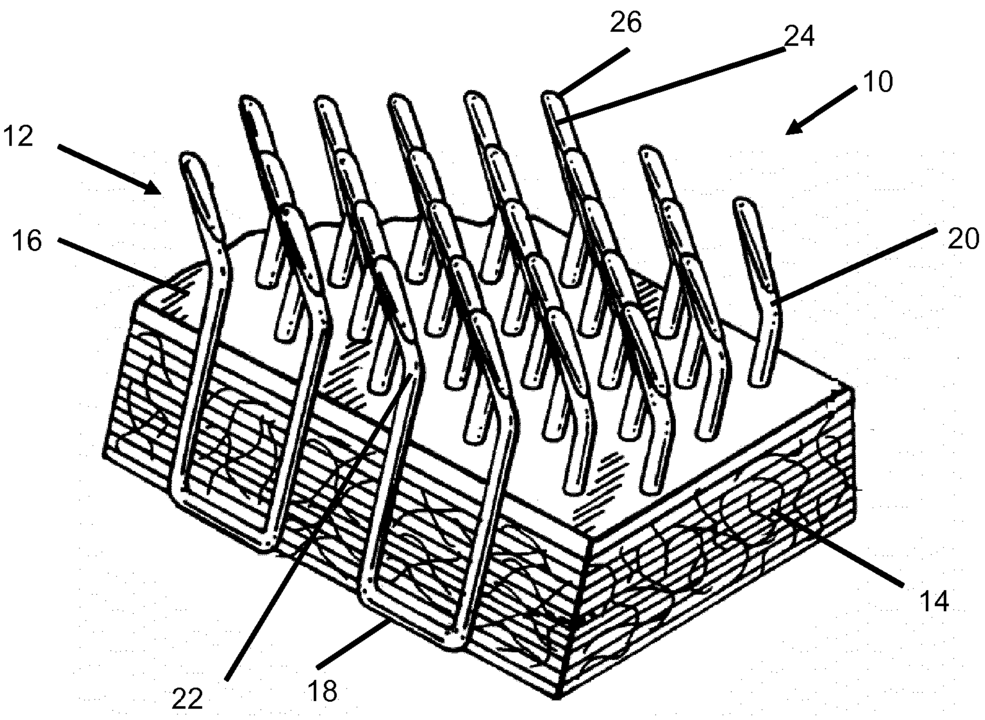

Fig. 1

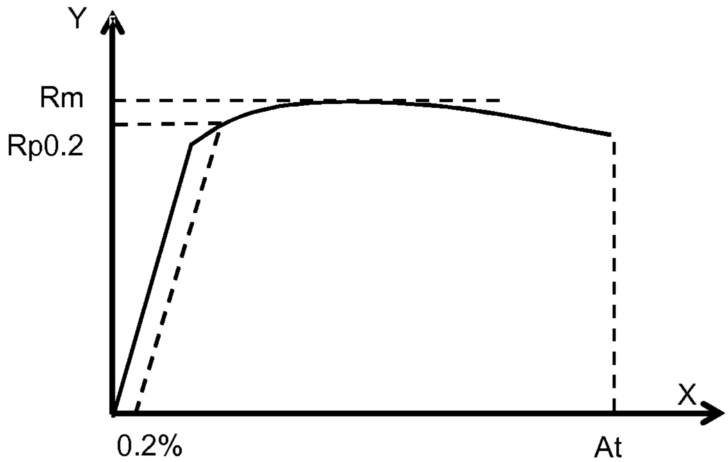

Fig. 2

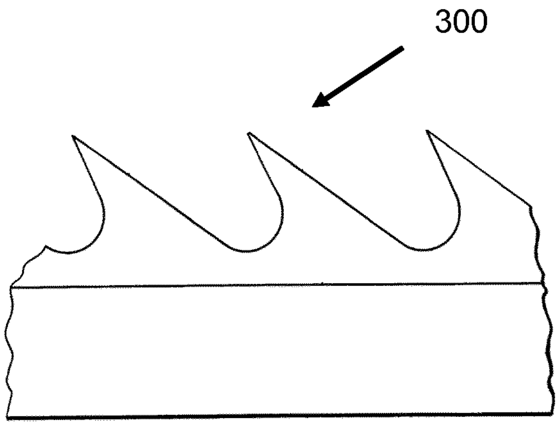

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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