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(54) Multi-filament with drawn steel core and annealed copper layer

(57) The present invention relates to a multi-filament product (10). The multi-filament product (10) comprises filaments (16) a having copper alloy layer (14) with annealed microstructure and a steel alloy core (12) with drawn microstructure. Furthermore, the filaments (16) in the multi-filament product (10) are coated with an electrical isolation coating (46). The present invention also relates to the use of the multi-filament product as heating element. The multi-filament product presents good conductivity, durability and strength.

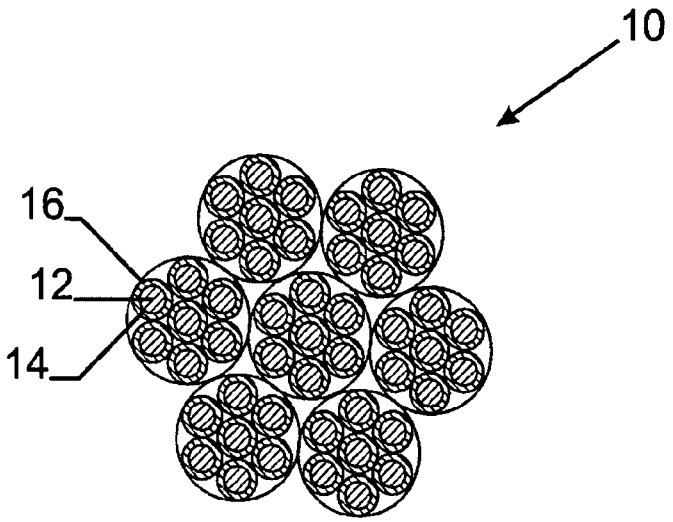

Fig. 1

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Description

Technical Field

[0001] The present invention relates to a multi-filament product. The present invention further relates to use of the multi-filament product as heating element.

Background Art

[0002] For a car seat, a heating element such as heating system or heatable textile is required to provide heating effect. It's a long time research to find a good heating element having a good balance between flexibility, corrosion resistance, strength and conductivity.

[0003] Generally yarns comprising bundles of filaments are applied in heating elements. Such yarns comprise up to hundred or more filaments. Up to now, the metal filaments are made from several different materials: they can be pure copper filaments, nickel plated copper filaments, steel filaments, copper plated steel filaments and steel plated copper filaments. All the above kinds of filaments have advantages and disadvantages.

[0004] Pure copper filaments have the best conductivity but low flexibility, low corrosion resistance and low strength.

[0005] Nickel plated copper filaments have a better corrosion resistance compared to pure copper filaments, but slightly lower conductivity.

[0006] Steel filaments have the best flexibility, strength and corrosion resistance, but they have a high electrical resistance.

[0007] Copper plated steel filaments have a better conductivity compared to stainless steel filaments, but a lower corrosion resistance. They have a better strength and flexibility compared to the pure copper filaments.

[0008] Steel plated copper filaments have a better corrosion resistance compared to the copper plated steel filaments.

[0009] Commonly the conductivity, flexibility and corrosion resistance are the main requirements for yarns used in heating element applications.

[0010] The flex life is one index or parameter for flexibility of the yarn and it is an indication of the resistance to rupture of the yarn under repetitive bending conditions. The flex life plays an important role such as for the use in antistatic brushes or the use as lead wire for electrodes or the use in car seat heating. The bigger the flex life, the better the filament.

[0011] WO 2009/147114 A discloses a yarn comprising multi-bundles of filaments having a copper core and stainless steel outer layer. An improved flex life is obtained by a predetermined torsion applied to the yarn. The diameter of the filament is between 7-32 μm.

[0012] US 7041943 discloses an electrical heating element used in car seat comprising wires with steel core and copper outer layer. The wires are further coated with electrical insulation. But due to the copper outer layer, the corrosion resistance of the wire is not very good.

[0013] It is desired to find a new product with a combination of great flexibility, corrosion resistance, strength and conductivity.

Disclosure of Invention

[0014] The object of the invention is to provide a multi-filament product with improved flexibility.

[0015] Another object of the invention is to provide the use of the multi-filament as heating element.

[0016] According to the present invention, a multi-filament product comprising filaments having a steel alloy core and a first layer of a copper alloy is provided, wherein the copper alloy has an annealed microstructure and the steel alloy has a drawn microstructure.

[0017] An annealed microstructure is a recrystallized microstructure which comprises substantially equi-axed grains. A drawn microstructure is a microstructure which comprises substantially non-equiaxed grains.

[0018] The use of filaments with the combination of the two kinds of microstructures, recrystallized microstructure of copper alloy layer and drawn microstructure of a steel alloy core in a multi-filament product, leads to an improved flexibility of the multi-filament product while the conductivity, corrosion resistance and strength remain unchanged.

[0019] The recrystallized microstructure of the copper alloy can be obtained by a heat treatment. While heating the filament with copper alloy layer having a drawn microstructure and steel alloy core having drawn microstructure under a determined temperature, the microstructure of the copper alloy will recrystallize and the steel alloy core keep its drawn microstructure.

[0020] The temperature of the heat treatment is determined by the annealing temperature of the copper alloy and the annealing temperature of the steel alloy. The temperature should be high enough to recrystallize the copper alloy on the one hand, and be low enough to make sure the steel alloy in the core does not recrystallize on the other hand. Thus the copper alloy gets an annealed microstructure while the steel alloy core retains the drawn microstructure. Preferably the determined temperature is between 100°C and 850°C.

[0021] The annealed copper alloy layer presents good conductivity and ductility. The copper alloy layer can be Cu-Ni alloy, Cu-Fe alloy or other alloy known by the person having ordinary skill in the art. Preferably the copper alloy layer has more than 99% copper. The higher the copper content of the copper alloy, the better the conductivity of the filaments and thus the better the conductivity of the multi-filament product.

[0022] The steel alloy core can be made of any kind of steel or steel alloy known by the person having ordinary skill in the art, i.e. stainless steel or plain carbon steel for good strength. Steel with drawn microstructure presents better strength than with an annealed microstructure.

[0023] To achieve a perfect balance between ductility,

conductivity and strength, the volume ratio of the copper alloy and the core of steel is determined. The ratio of the volume of the copper alloy and the volume of the steel alloy is between 80/20 and 10/90. Preferably the ratio of the volume of the copper alloy and the volume of the steel alloy is between 60/40 and 20/80. More preferably the ratio of the volume of the copper alloy and the volume of the steel alloy is between 40/60 and 30/70.

[0024] Preferably, the first layer of copper alloy is applied upon the steel alloy core uniformly. It means that the thickness of the first layer in any place around the steel alloy core has the uniform value.

[0025] According to the present invention, the diameter of the filament is more than 40μm, including the steel alloy core and the first layer of copper alloy. The 'diameter' here refers to the diameter of an imaginary circular radial cross section having a surface area identical to the average of the surface areas of cross sections of the filament. Commonly steel comprises inclusions, a steel 100% free of inclusions doesn't exist. In the patent publication WO 2009/147114 filaments with a diameter less than 40μm are described, the steel core is very thin for good conductivity, but the inclusions inside of the steel can penetrate through the thin steel layer during the manufacturing process, thereby creating fatigue fracture initiation points. In the present invention, the filaments have a diameter more than 40μm, in order to have enough thickness of the core of steel. Thus the inclusions inside the steel core can not penetrate through the steel core, as a result, the fatigue resistance improves a lot.

[0026] Preferably, the diameter of the filament is between 40μm and 400μm.

[0027] Preferably, the filaments are further coated with an electrical isolation coating upon the first copper alloy layer. It means that the individual filament has an electrical isolation coating. Such electrical isolation coating can eliminate hot spot and improve the corrosion resistance.

[0028] The electrical isolation coating can be a polymer coating, i.e. PVC, PVA, PTFE, FEP, MFA, PFA or PU.

[0029] The thickness of the electrical isolation can not be too thin and not be too thick. While too thin, it is hard to obtain a complete coverage of the filament with the coating. While too thick, the flexibility of the filament decreases.

[0030] Preferably the thickness of the electrical isolation coating is between 1μm and 10μm. More preferably, the electrical isolation coating is between 3μm and 7μm.

[0031] The multi-filament product can be one bundle, bundles twisted together or multi-strand structure.

[0032] Preferably the multi-filament is multi-strand structure, i.e. 7×7, 3×7 or 12×7, 6x6, 5x7, 8×9 cable construction. 'Multi-strand' refers to a gather of strands twisted together, while each strand comprises multiple filaments twisted together.

[0033] According to another object of the invention, the multi-filament product can be used as heating element, especially as car seat heating element.

Brief Description of Figures in the Drawings

[0034] Figure 1 shows the cross-sectional view of one embodiment with the structure of 7×7;

[0035] Figure 2 show the cross-sectional view of another embodiment with the structure of 3×7;

[0036] Figure 3 shows the cross-sectional view of a third embodiment with the structure of 12×7;

[0037] Figure 4 shows the cross-sectional view of a fourth embodiment according to the present invention;

[0038] Figure 5 shows the cross-sectional view of a fifth embodiment according to the present invention.

Mode(s) for Carrying Out the Invention

[0039] The multi-filament product is made from filaments comprising steel alloy core and first copper alloy layer.

[0040] The copper alloy can be pure copper, Cu-Ni alloy, Cu-Fe alloy or any other alloy known by the person having ordinary skill in the art. The steel alloy core can be pure steel, stainless steel, plain carbon steel or any other steel alloy known by the person having ordinary skill in the art. The stainless steel can be AISI 300 series such as AISI 302, 304, 316 or 316L, AISI 400 series such as AISI 430, AISI 625 or AISI 904.

[0041] The copper alloy layer can be applied to the steel alloy core by means of the technique of cladding. According to the technique of cladding, a strip of a suitable copper alloy of controlled composition and predetermined and desired thickness can be formed into a tube form. The width of this strip is somewhat greater or equal to the circumference of the steel alloy core to be covered. The strip is closed in a tube and welded on or around the steel alloy core.

[0042] Alternatively the copper alloy layer can be applied by inserting a steel alloy core wire into a copper alloy tube and closing the tube thereafter around the steel alloy core wire by conventional drawing techniques known by the person skilled in the art.

[0043] Alternatively the copper alloy layer can be applied to the steel alloy core by means of electrical or electrochemical deposition.

[0044] The filaments can be drawn to the final diameter by means of individual drawing process. First, the filaments comprising steel alloy core and first copper alloy layer plated upon the core are drawn from big diameter (original diameter) to the final smaller diameter by a drawing process individually. Such drawing process has been described in JP05-177243. During the drawing process, the diameter of the filament is reduced.

[0045] At the final diameter the steel alloy core and the first copper alloy layer both have a drawn microstructure.

[0046] At the final diameter the filaments having steel alloy core with drawn microstructure and first copper alloy layer with drawn microstructure are submitted to a heat treatment at a determined temperature. The temperature is determined by the annealing temperature of the copper

alloy and the annealing temperature of the steel alloy. The determined temperature should be high enough to recrystallize the copper alloy layer on the one hand, and be low enough to avoid recrystallizaton of the core of steel alloy. Thus the copper alloy layer gets a recrystallized microstructure while the steel alloy core retains the drawn microstructure after the heat treatment. For example, for heat treatment of the filament with stainless steel core and copper steel layer, the determined temperature is round 200°C, and for annealing the filament with 99%Cu-10%Ni alloy layer and stainless steel core, the temperature is round 400°C. The determined temperature is high enough to recrystallize the copper alloy at the layer and keep the drawn microstructure of the steel core without any change.

[0047] Additionally, the filaments may be coated with an electrical isolation upon the first copper alloy layer to avoid hot spot and improve the corrosion resistance. The electrical isolation can be any kind of the polymer known by the person having ordinary skill in the art, i.e. PVC, PVA, PTFE, FEP, MFA, PFA or PU.

[0048] Finally the filaments having copper alloy layer with annealed microstructure and steel alloy core with drawn microstructure (with or without electrical isolation coating) are bundled together to form a bundle or twisted together to form a strand. Furthermore the bundles or strands of the filaments are twisted together. A multi-filament product is obtained in this way. The multi-filament product may contain one bundle, plural bundles twisted together, or multi-strand twisted together.

[0049] Figure 1 illustrates the first embodiment. The multi-filament 10 has the structure of 7x7. The filaments 16 with the diameter of 48μm have stainless steel core 12 and first copper layer 14 with the volume rate of 38/62.

[0050] Figure 2 illustrates a second embodiment. The multi-filament 20 has the structure of 3×7. The filaments 26 with the diameter of 60μm have 90%Cu-10%Ni layer 24 and stainless steel core 22 with the volume rate of 35/65.

[0051] Figure 3 illustrates a third embodiment. The multi-filament 30 has the structure of 12×7. The filaments 36 with the diameter of 66μm have plain carbon steel core 32 and copper layer 34 with the volume rate of 59/41.

[0052] Figure 4 illustrates the fourth embodiment. The multi-filament 40 has the structure of 7×7. The filaments 48 with the diameter of 56μm have stainless steel 42 and first copper layer 44 with the volume rate of 66/34. Each filament has a further layer 46 of PU with the thickness of 6μm.

[0053] Figure 5 illustrates a fifth embodiment. The multi-filament 50 has the structure of 3×7. The filaments 58 with the diameter of 52μm have 99%Cu-1%Ni layer 54 and stainless steel core 52 with the volume rate of 64/36. Each filament has a further layer 56 of PFA with the thickness of 7μm.

[0054] A comparison test on flex life is done between the prior art products and the present invention. The flex life test is called car seat test also. In the test, the testing product is embroidered into a car seat. Then the car seat is cyclically loaded by a robot simulating a person getting in and out of a car. The number of the cycles is recorded till the product breaks. The prior art products are a yarn consisting of the filaments having copper core with drawn microstructure and stainless steel layer with drawn microstructure and a yarn consisting of the filaments having steel core with drawn microstructure.

[0055] Prior art yarns used in a car seat break before 20000 cycles are reached. The yarn according to the fourth embodiment reached much more than 20000 cycles without fracture.

[0056] It is obvious that the flex life of the present invention is greatly improved compared with the prior art products. The annealed microstructure of the copper alloy layer presents improved durability to the multi-filament product.

[0057] Furthermore, the conductivity of the invention multi-filament product is also improved compared with the prior products, while the strength of the invention multi-filament product keeps good performance.

[0058] The use of the present invention can be as heating element, especially as car seat heating element. The multi-filament product can be embroidered into a car seat. The multi-filament product provides good heat conductivity, durability and strength to the car seat.

Claims

1. A multi-filament product comprising filaments having a steel alloy core and a first layer of a copper alloy, **characterized in that** said copper alloy has an annealed microstructure and said steel alloy has a drawn microstructure.

2. A multi-filament product as claimed in claim 1, **characterized in that** said steel alloy is a stainless steel.

3. A multi-filament product as claimed in claim 1 or 2, **characterized in that** said copper alloy contains more than 99% copper.

4. A multi-filament product as claimed in any one of claim 1 to 3, **characterized in that** the ratio of the volume of said copper alloy and the volume of said steel alloy is between 80/20 and 10/90.

5. A multi-filament product as claimed in claim 4, **characterized in that** said ratio of said volume of said copper alloy and said volume of said steel alloy is between 60/40 and 20/80.

6. A multi-filament product as claimed in claim 5, **characterized in that** said ratio of said volume of said copper alloy and said volume of said steel alloy is between 40/60 and 30/70.

7. A multi-filament product as claimed in any one of claim 1 to 6, **characterized in that** said filaments have a diameter being more than 40μm.

8. A multi-filament product as claimed in any one of claim 1 to 7, **characterized in that** said filaments have a further electrical isolation coating upon said first steel layer.

9. A multi-filament product as claimed in claim 8, **characterized in that** the thickness of said electrical isolation coating is between 1μm and 10μm.

10. A multi-filament product as claimed in claims 9, **characterized in that** said thickness of said electrical isolation coating is between 3μm and 7μm.

11. A multi-filament product as claimed in any one of claim 8 to 10, **characterized in that** said isolation coating is polymer coating.

12. A multi-filament product as claimed in any one of claim 1 to 11, **characterized in that** the structure of said multi-filament product is 7x7, 3x7 or 12x7 cable construction.

13. Use of a multi-filament product as claimed in any one of preceding claims is as heating element.

14. Use of a multi-filament product as claimed in claim 14 is as car seat heating element.

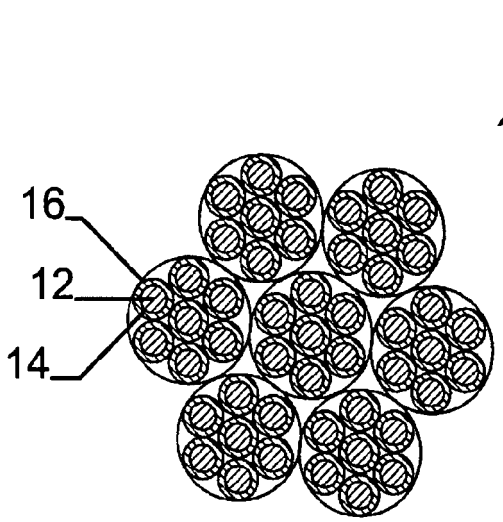

Fig. 1

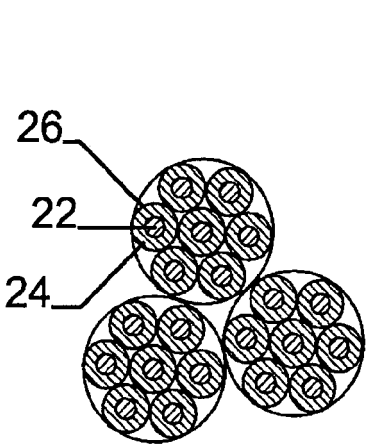

Fig. 2

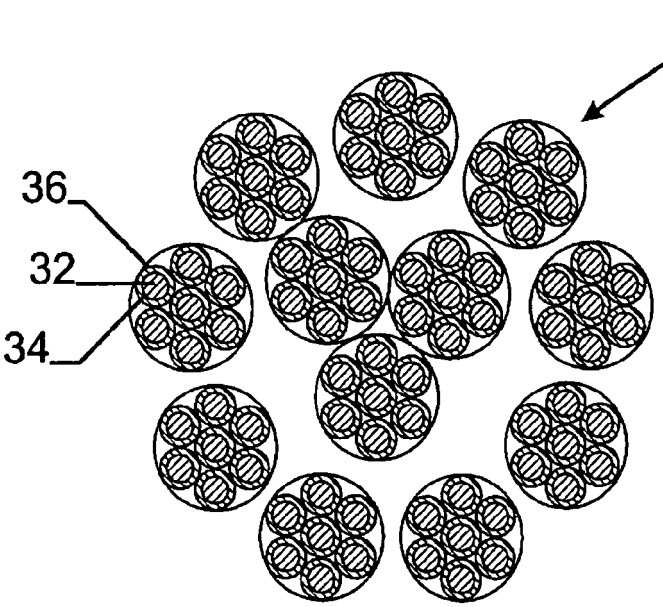

Fig. 3

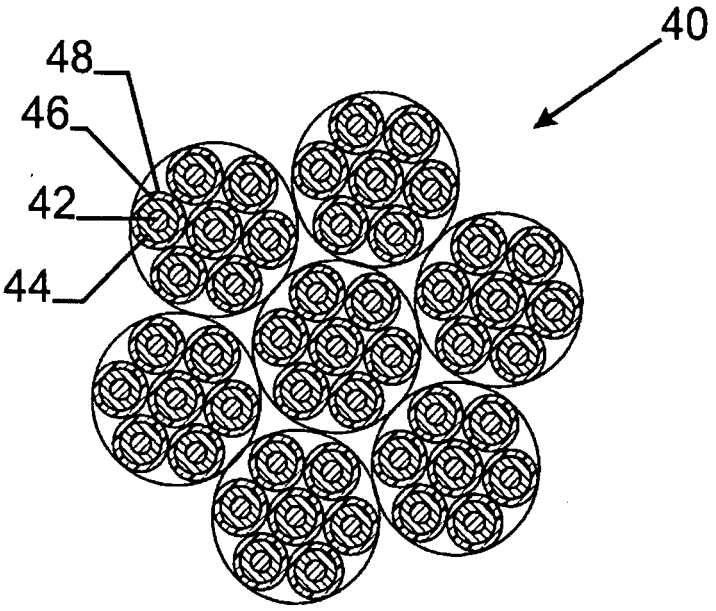

Fig. 4

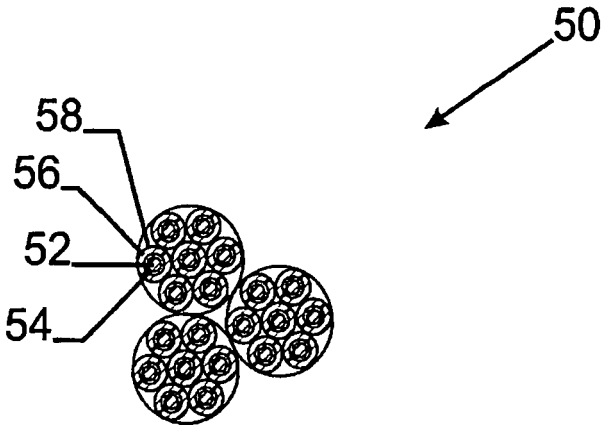

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 10 01 1924

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Y	US 2009/297883 A1 (KOPPENSTEINER EWALD [AT] ET AL) 3 December 2009 (2009-12-03) * paragraph [0006] * * paragraph [0022] *	1-14	
A	FR 2 647 271 A3 (BILLETTE DE VILLEMEUR PHILIPPE [FR]) 23 November 1990 (1990-11-23) * page 5, line 15 - page 6, line 13; figure 1 *	1	TECHNICAL FIELDS SEARCHED (IPC) D02G B21C H05B B32B B60N A47C H01B C22F C21D D03D H01L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	10 March 2011	Pollet, Didier

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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