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(54) **SHORT METAL FIBERS**

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(57) **ABSTRACT**

The present invention relates to short metal fibers. A set of short metal fibers, with an equivalent diameter ranging from 1 to 150 μm, comprises entangled and curved fibers. At least 10% of the short metal fibers are entangled, whereas the length of the curved fibers is distributed according to a gamma-distribution, having an average length preferably between 10 and 2000 μm.

Fig. 1a

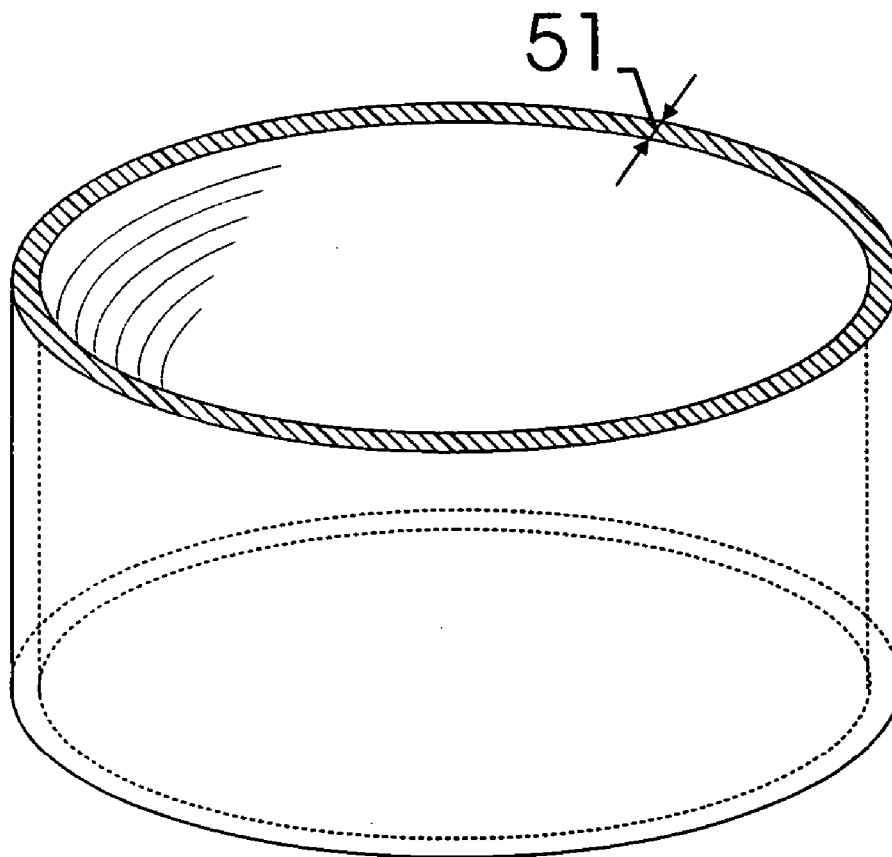Fig. 1b
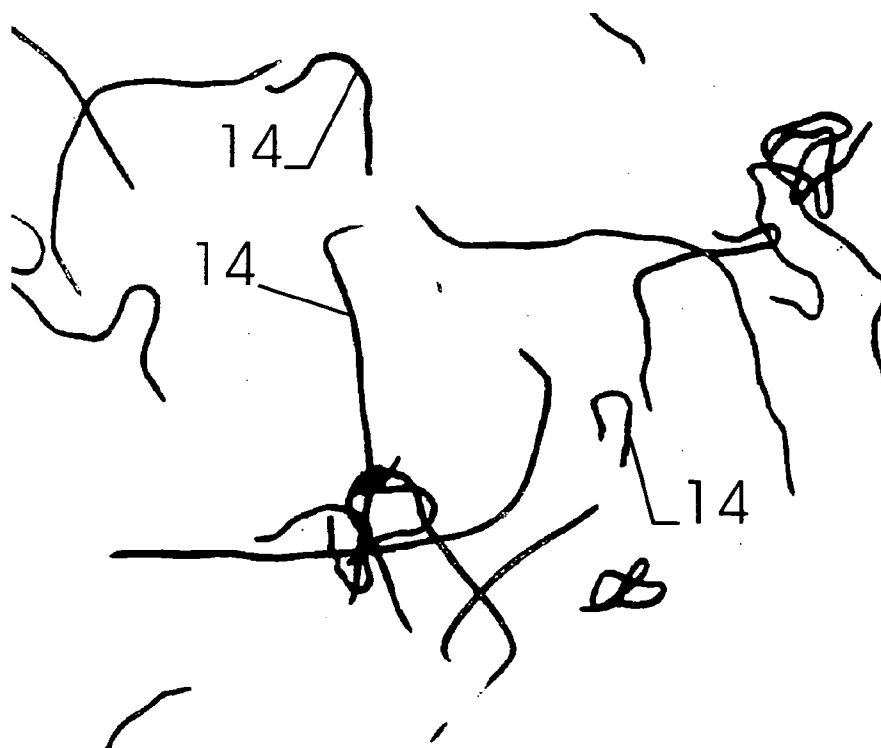
11

13

Fig. 1c

14

13
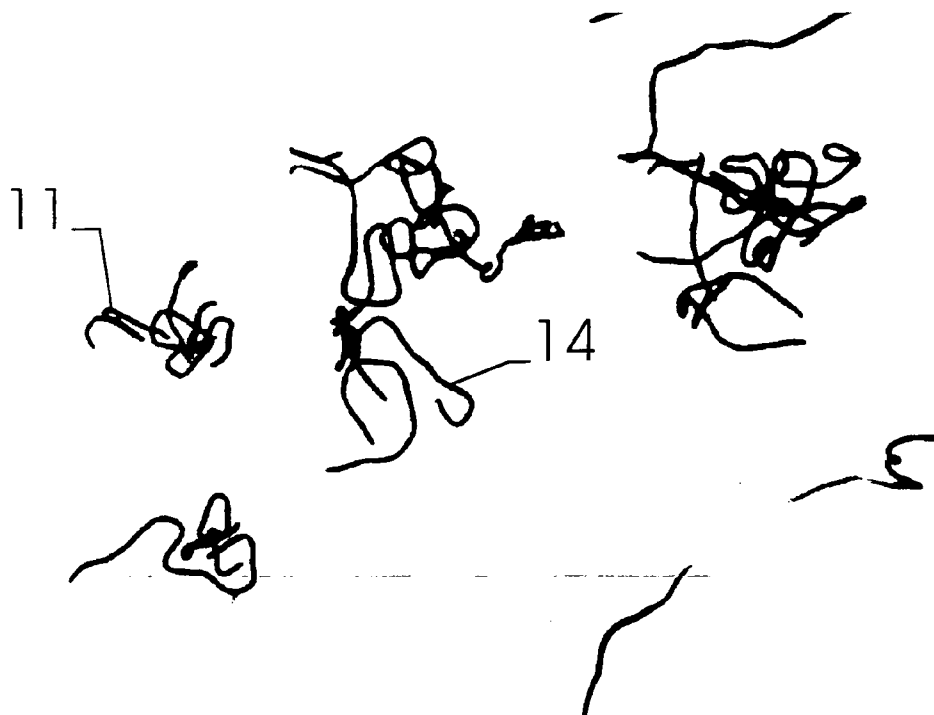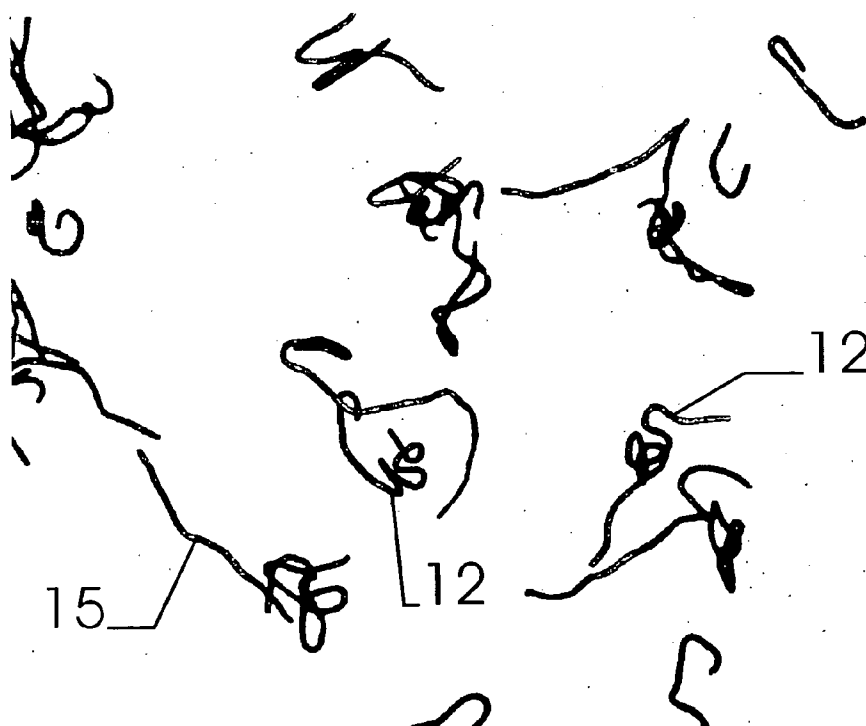
14

Fig. 1d

11

14

Fig. 1e

12

15

12

Fig. 1f

Fig. 2

Fig. 3

Fig. 4

Fig. 5

600

602   607   606

606

A   A'

610

608

604

Fig. 6a

610

608

608

602   600

606

612

614

604

607

Fig. 6b
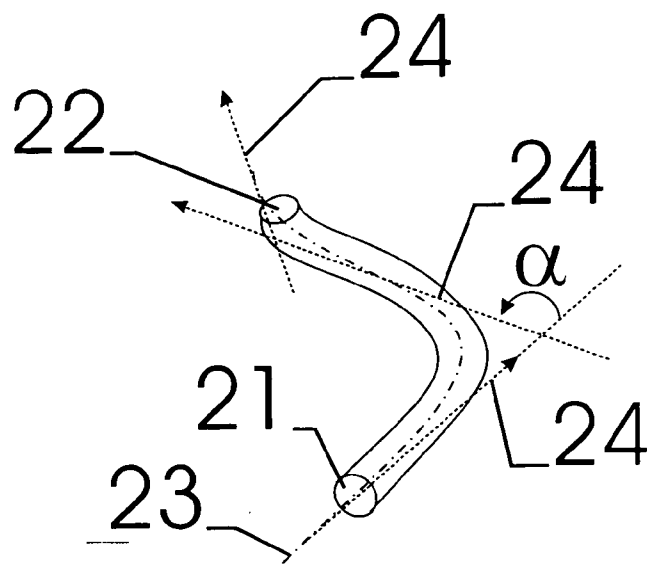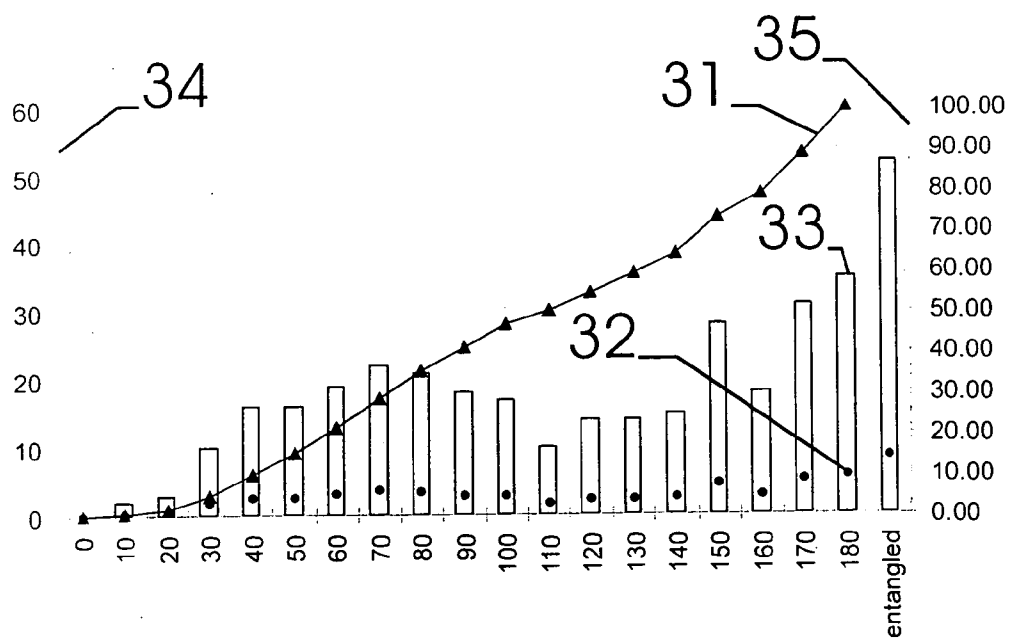
SHORT METAL FIBERS

[0001] The present application is a divisional of U.S. application Ser. No. 10/450,139, filed Jun. 12, 2003, the entire contents of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The invention relates to short metal fibers and to a sintered metal fiber product, using such fibers. The invention further relates to a method to produce short metal fibers and a sintered metal fiber product, using such fibers.
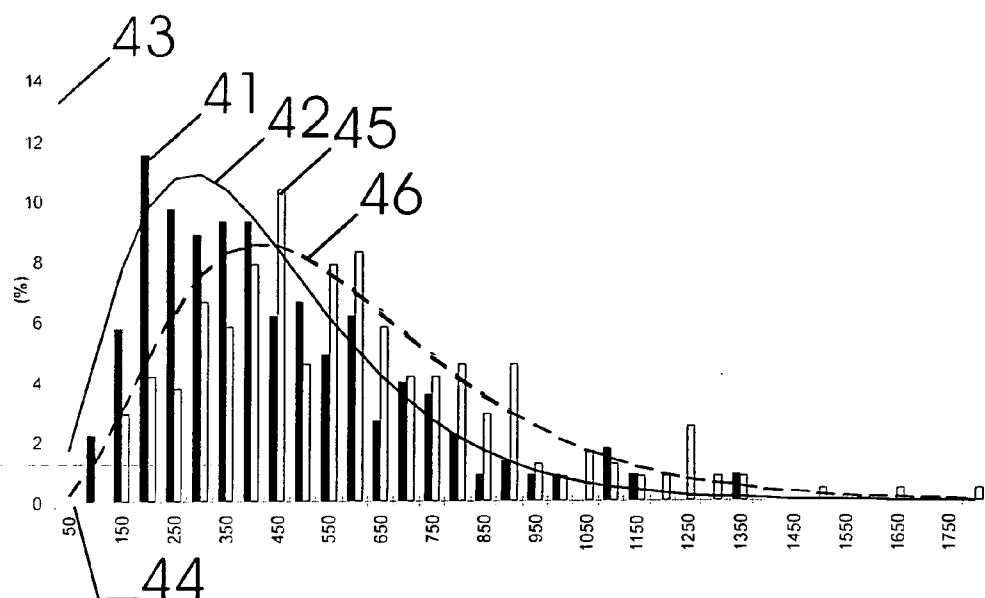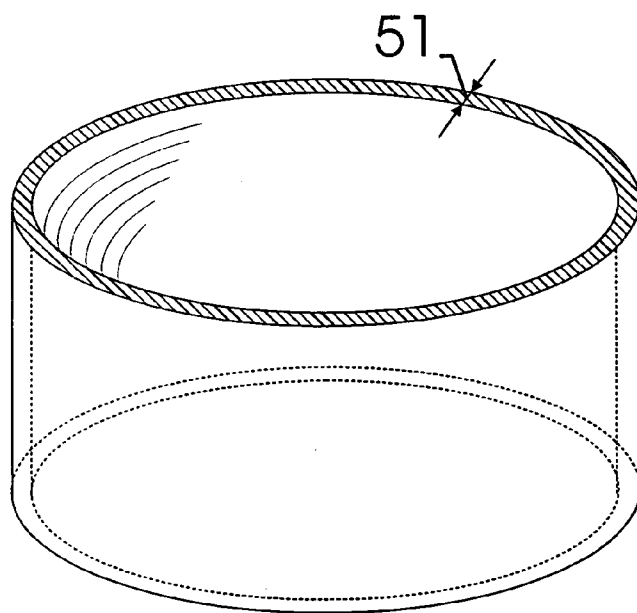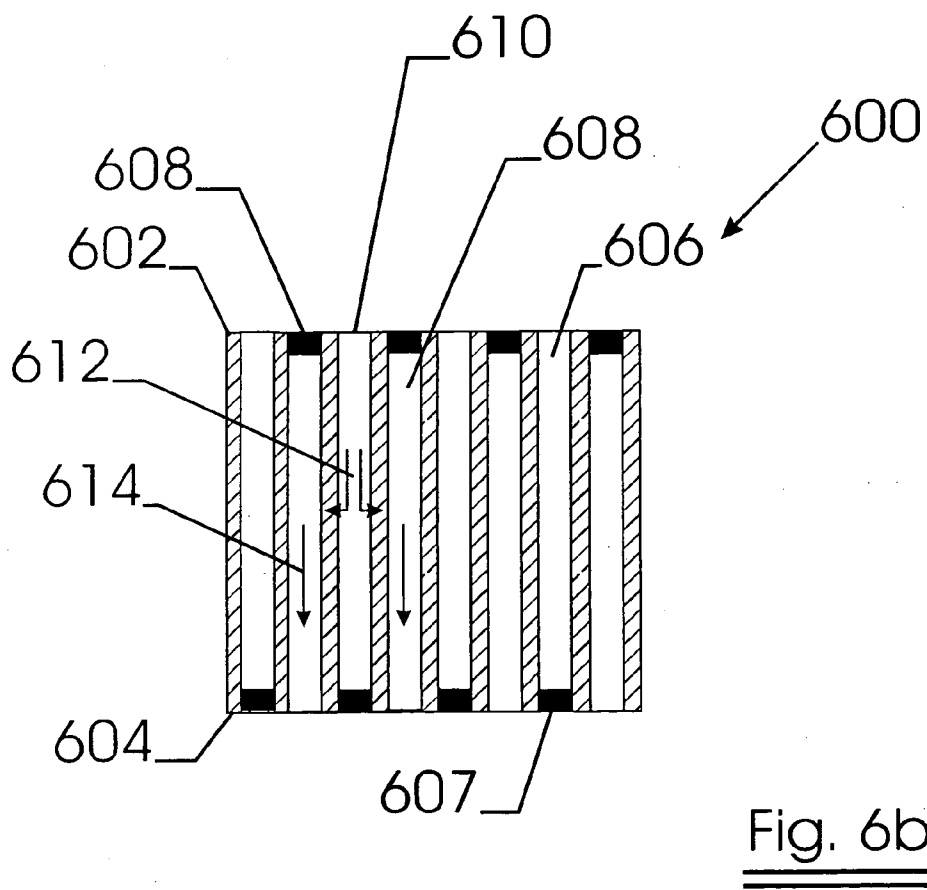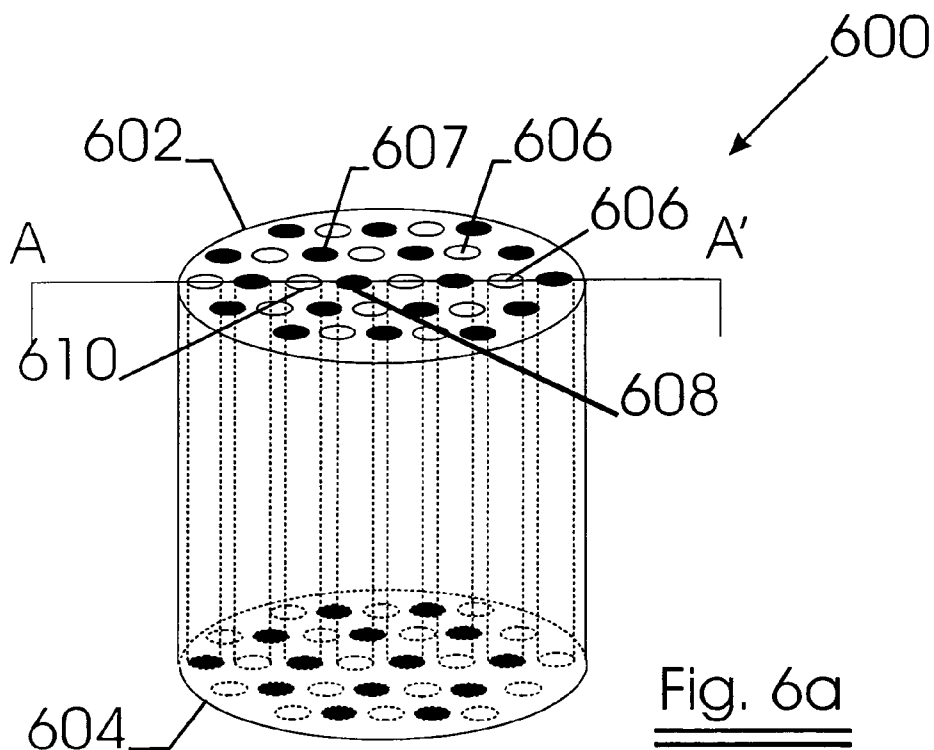
BACKGROUND OF THE INVENTION

[0003] Metal fibers having a rather flat cross section, with diameter less than 15 μm and a length of less than 400 μm are known from U.S. Pat. No. 4,703,898. These fibers have a crescent shape and have a small, point-like hook at both ends. This document further provides a method to produce such fibers.

[0004] JP2175803 describes similar short metal fibers, which have a curved shape.

[0005] Short metal fibers are also known from GB889583. These metal fibers may be undulated or "kinked" over their length. In this document, these terms mean that the major axis of the fibers change two or more times over the length of the fiber.

SUMMARY OF THE INVENTION

[0006] Most known short metal fibers are rather difficult to pour homogeneously in a mould, providing identical properties throughout the whole mould volume such as density and sizes of open space between adjacent fibers, although lots of improvements have been suggested.

[0007] The present invention relates to an alternative set of short metal fibers, which have an improved pourability. Further, the invention relates to sintered short metal fiber products and to a method to provide short metal fibers and sintered short metal fiber products.

[0008] A set of short metal fibers used to provide the temperature resistant material as subject of the invention is characterized by the presence of two different groups of short metal fibers, being "entangled" fibers and "curved" fibers.

[0009] A set of short metal fibers as subject of the invention comprises short metal fibers with an equivalent diameter "D" between 1 and 150 μm preferably between 2 and 100. Most preferably the equivalent diameter ranges between 2 and 50 μm or even between 2 and 35 μm such as 2, 4, 6.5, 8, 12 or 22 μm.

[0010] With the term "equivalent diameter" is meant the diameter of an imaginary circle, which has the same surface as the surface of a fiber, cut perpendicular to the major axis of the fiber.

[0011] The set of short metal fibers comprises entangled fibers. The number of entangled fibers in a set of short metal fibers as subject of the invention ranges from 5 to 35%. Preferably more than 10% of all short metal fibers in the set of short metal fibers are entangled. These fibers are hereafter referred to as "entangled fibers". To have a statistically

reliable percentage, a sample of at least 50 fibers, randomly chosen out of the set of short metal fibers are to be evaluated.

[0012] The percentage of entangled fibers is measured and calculated as:

% entangled fibers=100×(#entangled/#total)

wherein

#entangled=number of entangled fibers out of the sample;

#total=number of fibers out of the sample.

[0013] The entangled fibers of the set of short metal fibers as subject of the invention have an average length "Le", which is considerably longer as the average length of the curved fibers "Lc". The average length of the entangled fibers is at least 5 times the average length of the curved fibers. Preferably, the average length of the entangled fibers is more than 10 times the average length of the curved fibers. Preferably, the average length of the entangled fibers is larger than 200 μm, or even more than 300 μm, most preferably more than 1000 μm. the entangled fibers may be entangled with themselves (individually) or may be entangled together with some other entangled fibers. The entangled fibers, either individually or together with other entangled fibers, cannot be individualized as an essentially straight fiber out of the shape which is defined by the entanglement of the fibers. The major axis of each fiber changes so often and unpredictably, that the fiber may be entangled in many different ways. Some of the fibers are present in a shape, which resembles to a clew. The effect is comparable to the so-called pilling effect, well known in the textile industry, and in carpet industry more in particular. One or more fibers get trapped into a small ball. The trapped fibers may not be separated from this ball anymore. Other fibers look more like a pigtail. The are characterized by a major axis which changes several times in an unpredictable way, so a relatively chaotic shape may be provided.

[0014] The other short metal fibers out of the set of short metal fibers are hereafter referred to as "curved" fibers

[0015] The average length "Lc" of the curved fibers of the set of short metal fibers may range from 10 to 2000 μm, preferably from 30 to 1000 μm such as 100 μm, 200 μm or 300 μm. When a length distribution is measured from these curved fibers as part of a set of short metal fibers as subject of the invention, a gamma-distribution is obtained. This gamma-distribution is identified by an average length Lc and a shape factor "S". According to the present invention, the gamma-distribution of the length of the curved fibers, has a shape factor S ranging between 1 and 10.

[0016] For average lengths Lc larger than 1000 μm, usually a shape factor S lager than 5 is measured. For average lengths Lc between 300 μm and 1000 μm, a shape factor S between 2 and 6 is usually measured. For average lengths Lc smaller than 300 μm, usually a shape factor S smaller than 3 is measured. To have a statistically reliable distribution, at least 50 curved fibers, randomly chosen out of the set of short metal fibers are to be measured.

[0017] The L/D ratio of a set of short metal fibers as subject of the invention has an L/D-ratio of more than 5, preferably more than 10, wherein L is the average length of all fibers, present in a representative sample of fibers from the set of short metal fibers. As described above, this sample

comprises at least 50 fibers out of the set of short metal fibers. Preferably, but not necessarily, the curved fibers out of a set of short metal fibers as subject of the invention has an Lc/D-ratio of more than 5, preferably more than 10.

[0018] Further, a majority of these curved fibers have a major axis, which changes over an angle of at least 90°. This angle is the largest angle, which can be measured between two tangents of this major axis. Preferably, 40% of the curved fibers has a major axis, changing more than 90°, e.g. more than 45%, or preferably more than 50%. To measure these curves of the major axis, a microscopic image with appropriate enlargement is taken from several short metal fibers. Using a computer imaging system, the tangents of the major axis and the largest angle between them is calculated. To have a statistically reliable sample, at least 50 curved fibers, randomly chosen out of the set of short metal fibers are to be measured.

[0019] Such a set of short metal fibers has several advantages. A set of short metal fibers as subject of the invention has good pouring behavior.

[0020] Further, when short metal fibers as subject of the invention are poured, e.g. in a specific three-dimensional mould or on a flat surface, numerous contact points can be noticed between the short metal fibers. They are, so to say, ready to be sintered without a major force which is normally to be applied before sintering. The amount of contact points is present without requiring a force, which is not the case when the diameter of the short metal fibers extends beyond 150 μm. One understands that, if necessary to increase even more the number of contact points, or to decrease the pore volume and/or size, such forces may be applied before or during further processing.

[0021] Once poured, a set of short metal fibers as subject of the invention has an apparent density in the range of 10 to 40%, according to ISO 787-11. The pores between the short metal fibers are very small, but the number of pores is sufficiently large to provide an apparent density which is typically between 10 and 40%. A porosity, calculated as indicated below, ranges between 60 and 90%.

Porosity (%)=100%−apparent density (%)

[0022] The volumes between the fibers are similar throughout the poured volume, so providing an isotropic volume.

[0023] Short metal fibers as subject of the invention may be obtained by a method comprising the following steps:

[0024] individualizing the metal fibers by a carding operation;

[0025] providing the set of short metal fibers by cutting or entangling and sieving the set of short metal fibers, preferably by using a comminuting machine.

[0026] First, metal fibers, being present in a bundle of fibers, in a yarn or a textile structure, or even as staple fibers, are individualized to some extend by a carding operation.

[0027] These more or less individualized fibers are brought into a comminuting device. In this device, each fiber is cut into short metal fibers by fast rotating knifes. The blade of these knifes, having a certain blade thickness, encounter or 'hit' the fibers usually in radial direction. The fibers are mechanically plastically deformed and entangled

or possibly broken into a smaller length. Due to the centrifugal force, the so provided short metal fibers (curved or entangled) are blown outwardly against the external wall of the comminuting device. This external wall comprises a sieve with well-defined openings. According to these openings, short metal fibers with a certain length may pass through the sieve, whereas too long short metal fibers will stay in the comminuting device and possibly be hit once again, until the lengths are sufficiently small to pass the sieve, or until they are entangled enough to allow passage through the sieve.

[0028] The alloy of the metal fibers is to be chosen in order to provide required properties such as temperature resistance or electrical conductivity. Stainless steel fibers out of AISI 300-type alloys, e.g. AISI 316L or fibers based on INCONEL®-type alloys such as INCONEL®601 or NICROFER®-type alloys such as NICROFER® 5923 (hMo Alloy 59) and NICROFER 6023, or fibers based on Fe—Cr—Al alloys may be used. Also Ni-fibers, Ti-fibers, Al-fibers, Cu-fibers or fibers out of Cu-alloy or other alloys may be used.

[0029] Metal fibers may e.g. be bundle drawn or shaved, or provided by any other process as known in the art.

[0030] The short metal fibers as subject of the invention may be used to provide a sintered product. The method of manufacturing a sintered product comprises the steps of:

[0031] providing a set of short metal fibers;

[0032] pouring said set of short metal fibers into a three-dimensional mould or on an essentially plane surface;

[0033] sintering said set of short metal fibers to form a sintered product.

[0034] Possibly, before the sintering, the short metal fibers are pressed together to improve the coherency and/or to change the density.

[0035] Alternatively, the short metal fibers are brought in a suspension, using an appropriate agent or a mixture of appropriate agents.

[0036] The suspension is brought into a mould or poured onto an essentially plane surface. In a subsequent step the suspension liquid is removed, e.g. evaporated or sucked out. The mould, comprising the short fibers is then subjected to a sintering process in which all non-metal fiber elements are removed and in which a sintering between the metal fibers is obtained.

[0037] The sintering conditions are dependent upon the alloy and the properties required by the short metal fibers and the final sintered metal fiber product.

[0038] A great advantage of the method of the present invention is that the set of short metal fibers can easily be poured homogeneously; resulting in isotropic properties over the whole volume of the sinter metal fibers product. For example the density and the sizes of the pores are homogeneous over the whole volume of the product.

[0039] Another advantage of sintered products according to the present invention is their high porosity.

[0040] As indicated above, the short metal fibers will arrange themselves providing a three dimensional fiber

structure, with numerous small pores and numerous contact points. The pores are characterized by a relatively small size.

[0041] Applying forces on the short metal fibers during sintering may decrease pore size and porosity.

[0042] The porosity of a sintered product according to the invention is equal to the porosity of the poured fibers, as described above. The fibers do not have to be put under pressure to form a coherently sintered volume. This means that the porosity ranges generally between 60 and 90%. The porosity is for example 70, 80 or 85%.

[0043] However, dependent on the type and level of pressure, the porosity may be lowered to 49% if necessary, for example by cold isostatic pressing.

[0044] According to the specific use of the short metal fibers or the sintered metal fiber product, different metals and/or alloys may be used to provide the short metal fibers or the sintered metal fiber product.

[0045] Sintered short metal fiber products may have different shapes, according to the specific requirements of their application. Short metal fibers may be sintered into flat plates, rings, cylindrical or tube like shapes. Also more complex shapes such as monolithic structures may be obtained.

[0046] Sintered products may be used for different applications.

[0047] They may be used as a filtering device, for example a filtering device to filter gases or liquids.

[0048] The alloy of the metal fibers may be chosen in order to provide the filtering device the required properties such as temperature resistance and chemical resistance. Consequently, the filtering device may be used for high temperature applications, for example for the filtration of hot gases or for the filtration of corrosive gases or liquids.

[0049] The filtering device may have any shape. Preferred shapes are flat plates, rings, or cylindrical or tube like shapes.

[0050] When a sintered product as subject of the invention is used as a filtering devices, especially after being isostatically pressed, such filtering device may have an absolute filter rating of 0.5 μm up to 20 μm. Usually, the absolute filter rating may range between ⅓ and ½ of the equivalent diameter of the short metal fibers used.

[0051] A filtering device according to the present invention can thus be used for microfiltration applications, for example for the filtration of air in clean labs or in product rooms of electronic components.

[0052] A sintered product according to the present invention is in particular suitable to filter diesel exhaust gases.

[0053] A product as subject of the present invention may also be used as a carrier for catalysts. Therefore, commercially available catalyst can be applied on a sintered product.

[0054] A sintered product on which a catalyst is applied, hereinafter referred to as the catalyst, can be used to treat exhaust gases such as exhaust gases from incinerators or diesel engines, thereby removing harmful substances, such as NO_x, NH_3, CO, dioxins, O_3.

[0055] The catalyst is characterised by a porous open structure and a high specific surface. At the same time it is characterised by a high strength. Since the sintered product may withstand high temperatures, the catalyst can be used at high operating temperatures.

[0056] All these features result in a catalyst having a high efficiency of catalytic conversion.

[0057] Furthermore, a sintered product according to the present invention may be used as a catalytic filter which combines particle and/or dust retention and catalytic conversion of harmful components.

[0058] A sintered product may also be used as heat exchanging device. e.g. in Stirling engines, where a sintered product may be mounted in the passage of the working fluid or gas. Such device is also referred to as heat recuperator. The sintered product is heated when the working fluid or gas passes from the hot to the cold chamber of the Stirling engine. Afterwards, the heat, captured in the sintered product is regenerated when the cold working fluid or gas passes again through the sintered product, while it flows back to the hot chamber of the Stirling engine.

[0059] A three-dimensional sintered product according to the present invention can also be used a porous mould, for example as a mould to form glass products such as windshield glass.

[0060] Surprisingly, another use of a set of short metal fibers as subject of the invention is found by blending a set of short metal fibers with a ceramic matrix or ceramic or high-temperature resistant glue. A blend of short metal fibers and ceramic matrix or ceramic or high temperature resistant glue, up to 15% or even 20% by weight of short metal fibers, seems to resist thermal expansions to a larger extend, compared to the pure ceramic or high temperature resistant glue, once the glue or matrix comprising short metal fibers are cured. A higher resistance to thermal cracks in the glue was obtained. Preferably, the set of short metal fibers represents at least 0.5% of weight of temperature resistant material. Positive results were obtained especially when a set of short metal fibers is used which comprises entangled and curved fibers of which more than 10% of the set of short metal fibers are individually entangled fibers.

[0061] Surprisingly, only a relatively small change in electrical conductivity was noticed when the amount of the set of short metal fibers is kept lower than 10% by weight of the temperature resistant material, e.g. in the range of 1% to 9.5%, in the mean time providing sufficient resistance to thermal shocks and cracks. Higher percentages by weight of a set of short metal fibers may be used, e.g. more than 15% or even more than 20% or 30%, however such percentages of weight are not absolutely necessary to obtain a sufficient resistance to thermal shocks.

[0062] This effect is not restricted to short metal fibers as subject of the invention, but was also noticed using other short metal fibers. However the presence of entangled fibers plays an important role for the improvement of the thermal shock resistance. On the other hand, the presence of the curved fibers provides better pourablity and mixing behavior into the ceramic matrix or glue.

[0063] Preferably, ceramic matrices or ceramic glues based on SiO_2, Al_2O_3, ZrO_2 and/or MgO are used.

BRIEF DESCRIPTION OF THE DRAWINGS

[0064] The invention will now be described into more detail with reference to the accompanying drawings wherein

[0065] **FIGS. 1A, 1B**, 1C, ID, 1E and 1F are images of short metal fibers, all being part of a set of short metal fibers as subject of the invention.

[0066] **FIG. 2** shows a curved fiber being part of a set of short metal fibers as subject of the invention.

[0067] **FIG. 3** shows a graph of the length distribution of a set of short metal fibers as subject of the invention.

[0068] **FIG. 4** shows a graph of the curvature distribution of the curved fibers out of a set of short metal fibers as subject of the invention.

[0069] **FIG. 5** shows a sintered metal fiber product as subject of the invention.

[0070] **FIGS. 6***a* and 6*b* show a sintered product having a monolithic structure.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

[0071] A preferred embodiment of a set of short metal fibers as subject of the invention is shown in **FIGS. 1A, 1B**, 1C, 1D, 1E and 1F, which all show short metal fibers out of the same set of short metal fibers as subject of the invention. The short metal fibers, having an equivalent diameter of 22 μm, are obtained by providing a bundle of AISI 316L bundle drawn fibers of a carding device and further to a comminuting device. As may be seen from **FIG. 1A** to 1F, the shape of the short metal fibers may be very different. Some short metal fibers are clearly entangled fibers, such as fibers **11**, **12** and **13**. Fibers **12** are more curled irregularly, providing a non-defined shape. Fibers **13** are individually entangled to a non-defined shape. Fibers **11**, **12** and **13** are to be understood as "entangled fibers". Other fibers **14** are clearly curved, although the curling angles are unpredictably. Some fibers, such as fiber **15**, may have a limited curvature. An example of such a curved fiber is shown schematically in **FIG. 2**. A curved fiber has two ends, being a first end **21** and a second end **22**. A major axis **23** connects the center of the transversal cuts over the whole length of the fiber. The direction of the major axis **23** changes over an angle α. Angle α is absolute value of the largest angle which can be measured between two vectors **24** having a direction equal to the tangent of the major axis, starting point being a point of the major axis, and a sense pointing from first end **21** to second end **22**.

[0072] **FIG. 3** shows the angle distribution of the change of major axis of the curved fibers of the set of short metal fibers from **FIGS. 1A** to 1F. A sample to 316 fibers, randomly chosen out of the total set of short metal fibers was taken. Each bar **33** in the graph represents the number of fibers (to be read at the left ordinate **34**), having a major axis changing with an angle α, α being smaller than the angle value underneath that bar, which is related to that bar, but larger than the angle, related to the bar at its left side. E.g. the bar related to 90°, indicates the number of curved fibers, having an angle α smaller than 90°, but larger than 80°.

[0073] Related numbers are summarized in Table I

TABLE I

angle α of fibers	number in sample	% curved with angle α/total curved fibers	% curved with angle α or entangled/total fibers
0	0	0.00	0.00
10	2	0.65	0.55
20	3	0.97	0.83
30	10	3.24	2.77
40	16	5.18	4.43
50	16	5.18	4.43
60	19	6.15	5.26
70	22	7.12	6.09
80	21	6.80	5.82
90	18	5.83	4.99
100	17	5.50	4.71
110	10	3.24	2.77
120	14	4.53	3.88
130	14	4.53	3.88
140	15	4.85	4.16
150	28	9.06	7.76
160	18	5.83	4.99
170	31	10.03	8.59
180	35	11.33	9.70
entangled	52	—	14.40
total entangled	52		
total curved	309		
total	361		

[0074] Line **31** indicates the cumulative curve of the number of curved fibers having an angle α, less than the angle value in abscissa. This number is expresses, as indicated on the right ordinate **35**, in percentage compared to the total number of curved fibers in the sample. More than 50% of the curved fibers have a major axis direction changing more than 90%.

[0075] As also indicated in **FIG. 3**, more than 10% of all short metal fibers out of the set of short metal fibers are entangled fibers. This is indicated by the dots **32**, which represent the percentage of fibers, also to be read on the right ordinate **35**, comprised in the related bar **33**, compared to the total number of short metal fibers out of the sample taken from the set of short metal fibers.

[0076] **FIG. 4** shows the length distribution of the curved fibers of two sets of short metal fibers as subject of the invention.

[0077] A first length distribution **41**, indicated with black bars, is a length distribution of the curved fibers of a set of short metal fibers, having an equivalent diameter of 8 μm. The set of short metal fibers was provided using bundle drawn stainless steel fibers, alloy AISI 3O2. A representative and randomly chosen sample of 227 fibers was taken. An average length Lc of 420 μm was found. The length distribution is a gamma-distribution **42**, being characterized with a shape factor S being 3.05. The bars of distribution **41** is to be understood as the percentage of curved fibers out of the sample (read in ordinate **43**), which has a length (expressed in μm and indicated in abscissa **44**) in the range with upper limit as indicated underneath the bar, and lower limit being the length indicated under the adjacent bar left if it. In the

same way, the gamma-distribution reads the percentage of fibers in ordinate **43** in the range indicated on the abscissa **44** as explained above.

[0078] Another length distribution **45** is shown in **FIG. 4**, indicated with white bars, which is a length distribution of the curved fibers of a set of short metal fibers, having an equivalent diameter of 12 μm. The set of short metal fibers was provided using bundle drawn stainless steel fibers, alloy AISI 316L. A representative and randomly chosen sample of 242 fibers was taken. This length distribution accords to a gamma-distribution **46**, which is characterized with a shape factor S being 3.72. An average length Lc of the curved fibers of 572 μm was measured.

[0079] A sintered metal fiber product as subject of the invention may be provided as shown in **FIG. 5**. The short metal fibers used have a diameter of 22 μm. The thickness **51** of the medium is approximately 40 mm. The sintered metal fiber product has a porosity of 81%. The short metal fibers were stainless steel bundle drawn fibers, Fecralloy® type alloy. Such ring-like shape may be used as heat regenerating device in a Stirling engine. An alternative sintered metal fiber product, as subject of the invention is obtainable by sintering short metal fibers as subject of the invention to a flat shape, plate-like product. E.g. short metal fibers of alloy AISI 444, having an average length of 1000 μm and an equivalent diameter of 65 μm, obtained by a shaping process as explained in WO9704152, are sintered to a flat volume with thickness of 2.35 mm and a weight of 5226 g/m². A porosity of 72% and an absolute filter rating of 92 μm was obtained. When a similar product, using short metal fibers as subject of the invention, being bundle drawn fibers of an equivalent diameter of 12 μm and an average length L of 800 μm, isostatically pressed using 800 Bar, a porosity of 70% was obtained, and an absolute filter rating of 5.3 μm.

[0080] One understand that other shapes, such as flat plates, or tube-like or cylindrical shapes may be obtained. Even monolithic structures, e.g. to be used in a diesel exhaust filter, filtering soot from the exhaust gas, may be obtained.

[0081] **FIG. 6***a* shows a monolithic structure **600** comprising a set of short metal fibers. **FIG. 6***b* shows a cross-section along line A-A'.

[0082] The monolithic structure shown in **FIG. 6** is in particular suitable to filter exhaust gases.

[0083] The gas to be filtered enters the monolithic structure at inlet side **602** and exits the monolithic structure at outlet side **604**.

[0084] The monolithic structure has a number of cells **606**. Each cell has a first end adjacent the inlet of the monolithic structure and a second end adjacent the outlet of the monolithic structure.

[0085] At least part of the cells is blocked at the second ends of the cell by a barrier **607**. The barrier comprises a material that does not allow the passage of the gaseous stream.

[0086] In the preferred embodiment of **FIG. 6 a** cell is either blocked at its inlet side as for example cell **608**; or at its outlet side as for example cell **610**.

[0087] Thus, the exhaust stream can not pass freely through the cells, but is obliged to pass through the walls to a neighbouring cell having an open outlet side.

[0088] For example exhaust gas entering cell **610** passes through the wall surrounding cell **610**, as indicated by the arrows **612**, for example to cell **608** through which it can leave the monolithic structure at the outlet side.

[0089] Possibly, the cell walls are coated with a catalyst or alternatively a catalyst is applied into the porous structure of the monolithic structure.

[0090] A three-dimensional sintered product according to the present invention can also be used a porous mould, for example as a mould to form glass products such as windshield glass.

[0091] A set of short metal fibers as of **FIG. 3**, was used to improve the resistance to thermal cracking and thermal shocks of a ZrO_2—MgO based ceramic glue.

[0092] A ceramic material, being a ceramic past, which may be used as ceramic glue, was prepared using 77 gram ZrO_2—MgO based compound and 10 gram of water. An amount of a set of short metal fibers having an average equivalent diameter of 22 μm, of which the length distribution is provided as indicated with **45** in **FIG. 4**, is mixed in this ceramic paste, as indicated in Table I.

[0093] The ceramic paste was heated to a temperature of 600° C., and this temperature was kept for 90 sec. after which it was cooled to ambient in 60 sec. The number of cracks on an equal surface was counted, and is resumed in Table II.

TABLE II

Temperature resistant matrix (ceramic matrix) (gram)	Set of short metal fibers of 12 μm (gram)	% of weight of short metal fibers (%)	Number of cracks (—)
77	0	0	20
77	2	2.5	16
77	4	4.9	8
77	8 (sample I)	9.4	0
77	8 (sample II)	9.4	2

[0094] An identical result was obtained using a set of short metal fibers of 22 μm equivalent diameter.

    1. A method to provide a set of short metal fibers, comprising the steps of:

    individualizing the metal fibers by a carding operation;

    providing the set of short metal fibers by cutting or entangling and sieving the set of short metal fibers.

    2. A method to provide a set of short metal fibers as in claim 1, said providing the set of short metal fibers by cutting or entangling and sieving the set of short metal fibers is done using a comminuting machine.

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