(54) Title: DIESEL SOOT PARTICULATE FILTER MEDIUM
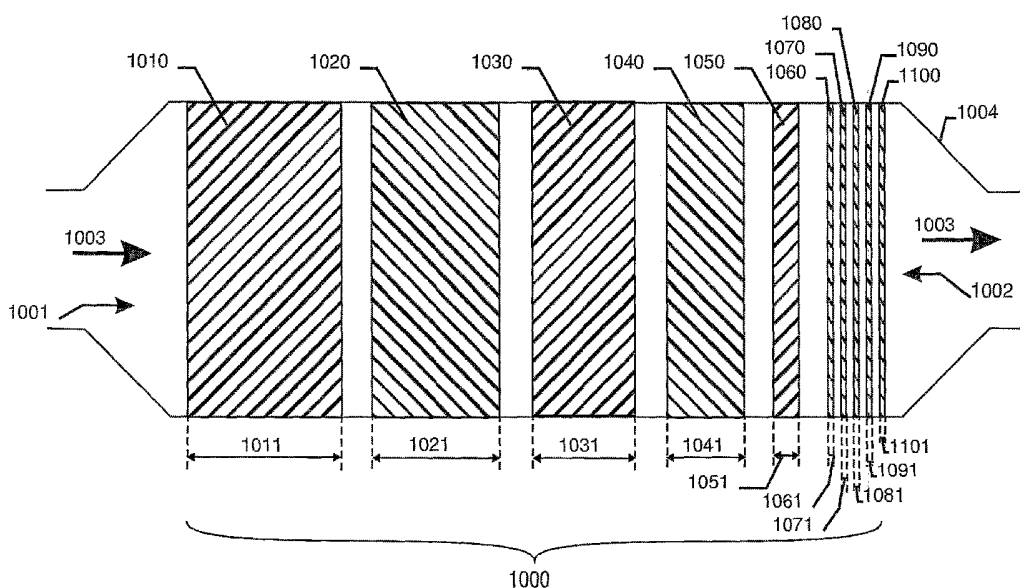
(57) Abstract: A diesel soot particulate filter medium, as subject of the invention comprises fibers, preferably metal fibers. The diesel soot particulate filter medium has a thickness T between its inflow side and its outflow side being equal or more than 5 cm. The S/V at the inflow side is more than 50 m²/m³ and the S/V at the outflow side is less than 30000 m²/m³, whereas S/V increases stepwise or gradually from the inflow side to the outflow side. S is the sum of all mantle surface of the fibers present in a volume V.

DIESEL SOOT PARTICULATE FILTER MEDIUM

Field of the invention.

The present invention relates to diesel soot particulate filters and to diesel soot particulate filter medium.

Background of the invention.

Diesel soot particulate filters comprising fibers such as metal or ceramic fibers are well known.

JP2002058939 describes a diesel soot filter, which has comprises a construction of porous materials, for which the meshes of the filter have been made finer in the direction of the flow of the exhaust gas to be filtered.

The filter either comprises several filter medium layers, one adjacent to the other, for which each layer has a defined mesh coarseness, or as an alternative the mesh coarseness changes gradually over the depth of the filter medium.

Summary of the invention.

It is the object of the present invention to improve the filtration properties of filters having such gradually changing mesh coarseness or filter fineness for the purpose of diesel soot filtration when fibers, as an example metal fibers or ceramic fibers are used to provide the filter media.

A diesel soot particulate filter medium as subject of the invention comprising fibers and the diesel soot particulate filter medium having an inflow side and an outflow side. The diesel soot particulate filter medium as subject of the invention is characterized in that the filter medium thickness T between said inflow side and said outflow side is equal or more than 5cm and the S/V at said inflow side being more than $50m^2/m^3$ while the S/V at the outflow side is less than $30000m^2/m^3$ and S/V

-2-

increasing stepwise or gradually from said inflow side to said outflow side.

S is to be understood as the sum of all mantle surfaces of the fibers being present in a volume V.

At the inflow side of the diesel soot particulate filter medium as subject of the invention, the S/V is more than 50 m^2/m^3, preferably more than 100 m^2/m^3 or even more than 300 m^2/m^3. Advantageously, the S/V at the inflow side is less than 1000 m^2/m^3.

At the outflow side of the diesel soot particulate filter medium as subject of the invention, the S/V is less than 30000 m^2/m^3, preferably less than 28000 m^2/m^3 or even less than 25000 m^2/m^3. Advantageously, the S/V at the outflow side is more than 15000 m^2/m^3.

The diesel soot particulate filter medium as subject of the invention may comprise several layers of fiber media, one adjacent to an other. Each layer has an S/V being essentially equal throughout the whole volume V of the layer. The layers may be spaced from each other using appropriate spacing means, or may be present one in contact with the other.

The term "layer" herein used it to be understood as a volume-part of the filter medium, which has substantially equal properties throughout its volume.

The S/V is stepwise increasing from the inflow to the outflow side of the filter medium.

Alternatively, the diesel soot particulate filter medium as subject of the invention may comprise only one filter medium, for which the S/V gradually changes through the thickness of the media. The S/V is approximated by calculating the S for a volume V, being a section of the filter medium perpendicular to the flow direction, and having a thickness approximating 0. The S/V is gradually increasing from the inflow to the outflow side of the filter medium.

-3-

The term "filter medium thickness T" is to be understood as minimum distance between the inflow side and the outflow side of the diesel soot particulate filter medium. In case the diesel soot particulate filter medium comprises several individual layers of filter media, T is to be understood as the sum of minimum thickness' t_i of each individual layer i. T is more than 5cm, but advantageously, T is more than 8cm or even more than 10cm.

The diesel soot particulate filter medium as subject of the invention comprises or even consists of fibers.
Preferably, the fibers used for the filter medium, are metal fibers, such as bundle drawn or coil shaved fibers. Alternatively, metal wool may be used.

The alloy of metal or steel may be chosen dependent on the temperature range, which is to be withstood by the metal fibers. Stainless steel fibers of AISI alloys of the 300- or 400 series, or alloys such as Inconel® are to be preferred. In case high temperatures are to be withstood, alloys comprising Fe, Al and Cr are preferred, such as Fecralloy.

Most preferably, the filter medium comprising metal fibers, is sintered in order to bond the metal fibers.

The term "sum of mantel surfaces S" is defined as the accumulation of all mantle surfaces or the fibers, present in a volume V of the filter medium. The mantle surface of a fiber is the surface being essentially parallel to the axis of the fiber. This mantle surface may be calculated as

$$S = L * A$$

-4-

Wherein

→ L is the sum of the fiber lengths present in volume V;

→ A is the perimeter of the fibers present in volume V.

Fibers, providing the filter medium, are characterized by an equivalent
diameter (D), a surface shape and an "average length (LM) to
equivalent diameter"- ratio (LM/D).

With the term "equivalent diameter" is meant the diameter of an
imaginary circle, which has the same surface as the surface of a fiber
section, cut perpendicular to the major axis of the fiber. Fibers used to
provide the layers of the filter medium as subject of the invention, may
be in the range of $0.5\mu m$ to $100\mu m$, such as in the range of $2\mu m$ to
$75\mu m$, as an example in the range of $12\mu m$ to $50\mu m$, e.g. $25\mu m, 35\mu m$ or
$40\mu m$.
The ratio average length LM over equivalent diameter D, being LM/D is
preferably more than 5 or 10 or even more than 25 or 50, most
preferably more than 100.

The shape of the surface of the fibers may vary to a large extend. This
shape is defined by the geometrical figure of a radial cross section of
the fiber. This may e.g. be rectangular or square, circular, triangular, or
comprise a rather serrated section circumference. For most fibers used,
the shape of a radial section is essentially identical over the whole
length of the fiber. The shape defines to a large extend the perimeter A
of the fibers present in the diesel soot particulate filter medium.

Possibly, if the filter medium comprises different layers, the layers may
be sintered to each other to bond the different layers to each other.
The different layers may be sintered and brought to the required
porosity separately during a first sintering cycle. After being superposed
to each other, they are sintered to each other during a second sintering
cycle. Alternatively, the different layer may be superposed to each other

-5-

before sintering. During one sintering cycle, the layers are sintered and bond to each other by the sintering operation.

In case the metal fibers are obtained by shaving from a coiled plate as described more in detail in WO97/04152, a radial section of such metal fiber is essentially rectangular. The length of both sides are to be taken into account for calculating S of the volume comprising such fibers.

In case the metal fibers are obtained by bundled drawing, the metal fibers have an essentially circular of pentagonal radial section. It was found that the circumference of the fiber radial section is sufficiently approximated by using the circumference of the imaginary circle, having the same surface as the surface of the radial section of the fiber.

The S/V values of the diesel soot particulate filter medium may be tuned by adjusting the porosity of the medium, or a the porosity of a lyaer being part of the medium, or by selecting the fiber surface shape and the fiber equivalent diameter.

As an example, a diesel soot particulate filter medium is provided having a uniform porosity over its total volume. At the inflow side, relatively coarse fibers having a relatively large equivalent diameter are used. More towards the outflow side of the medium, the equivalent diameter of fibers decrease gradually.
In this case, whereas for each volume V chosen, an identical weight is obtained, the sum of mantle surfaces S of a volume V increases since finer fibers have an increases fiber mantle surface per fiber volume or fiber weight. As the porosity is equal over the whole volume of the filter medium, by selectively choosing the equivalent diameter of the fibers, one may provide a diesel soot particulate filter medium as subject of the invention.

Alternatively, a diesel soot particulate filter medium having a uniform porosity over its total volume may be provided, by selectively choosing

-6-

the fiber cross section shape. As an example, at the inflow side, fibers having an essentially circular cross section and an equivalent diameter d may be used. The surface of the cross section of these fibers is $\pi*d^2/4$. The mantle surface of these fibers is $\pi*d*L$, where L is the length of the fiber.

Further towards the outflow side of the filter medium, fibers having an essentially square section with side length a are used. a is chosen in such a way that $a^2 = \pi*d^2/4$. Therefor, d is the equivalent diameter of these square fibers. The mantle surface of these square fibers is $4*a*L$, which is larger than the mantle surface of the circular fibers at the inflow side of the filter medium.

Further towards the outflow side, rectangular fibers may be used, having a short side b and long side c. b and c are chosen in such a way that $b*c = \pi*d^2/4$, so d is the equivalent diameter of the rectangular fibers. The mantle surface of these rectangular fibers is $2*(b+c)*L$, which is larger than the mantle surface of the circular fibers and the square fibers upwards to the inflow side of the filter medium. The more to the outflow side, the dimensions of the sides b and c are chosen that the difference between b and c increases, whereas the equivalent diameter stays equal to d. hereby, the mantle surface of the fibers increase towards the outflow side of the filter medium. As over the whole filter medium volume the porosity is equal, the ratio S/V increases from the inflow to the outflow side by changing the shape of the fiber cross section.

As an other example, a diesel soot particulate filter medium is provided having identical fibers throughout the whole filter medium. At the inflow side, a higher porosity is provided, whereas towards the outflow side, the porosity is decreased. A decreasing porosity means that more fiber volume is to be present per volume towards the outflow side. Since all fibers are equal, this means that more mantle surface of fibers is to be present per volume towards the outflow side. By selectively choosing the porosities, the shape of cross section and the fiber equivalent diameter, one may obtain a diesel soot particulate filter medium as subject of the invention.

As a result, surprisingly it was found that diesel soot particulate filter media as subject of the invention, may have

- improved filter efficiency up to the range of 85% to 95% or even more than 99%, and this after a short loading time.
- an increased soot loading time and soot loading capacity even in a broad range of phase velocities from the exhaust gasses filtered.
- A minimized pressure drop, in spite of the relatively high filter medium thickness T, as significantly high porosity's may be used, ranging from 85% up to 99,5% or even more all the way through the filter medium.

It is understood that the filter medium may be provided with catalysts to obtain an oxidation of the trapped soot. Possibly, also catalytic compounds are provided to reduce the NO_x-content of the exhaust gas. Different catalysts may be provided through the depth of the filter medium.

A diesel soot particulate filter medium can be used to provide a diesel soot filter comprising a diesel soot particulate filter medium as subject of the invention. The diesel soot filter may additionally comprise other elements such as a filter housing or can, and means to regenerate the filter media for removing the soot trapped on the media.

Brief description of the drawings.

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

- FIGURE 1 schematically shows a diesel soot particulate filter medium as subject of the invention.
- FIGURE 2 schematically shows an other diesel soot particulate filter medium as subject of the invention.

-8-

– FIGURE 3 shows S/V curves from the embodiments ad described
    herein after.

Description of the preferred embodiments of the invention.

A diesel soot particulate filter medium 1000 as subject of the invention is
shown in FIGURE 1. A diesel soot particulate filter medium 1000, having
an inflow side 1001 and an outflow side 1002 for filtration of exhaust
gasses having a flow direction indicated with arrows 1003, is mounted in
a filter can 1004.

The diesel soot particulate filter medium comprises 10 layers of fiber
media, indicated 1010, 1020, 1030, 1040, 1050, 1060, 1070, 1080, 1090
and 1100. The layers are present one adjacent to the other. In FIGURE
1, it is shown that the layers are mounted separated one from the other,
however this separation is not essential for the purpose of the invention.
Alternatively, they may be mounted one into contact with the other.

Each layer has a thickness, as indicated 1011, 1021, 1031, 1041, 1051,
1061, 1071, 1081, 1091, 1101.
The filter medium thickness T is to be understood as the sum of the
thickness' of the layers.

For a first embodiment, the characteristics of the fiber media of the
layers, consisting of metal fibers, are listed in table I.

TABLE I

Layer number (-)	Fiber cross-section shape	Fiber perimeter (µm)	Fiber equivalent diameter (µm)	Layer thickness (mm)	Porosity (%)	S/V (m²/m³)
1010	Rectangular (54µm*21µm)	150	38	120	99.52	391
1020	Rectangular (54µm*21µm)	150	38	100	99.13	703
1030	Rectangular (54µm*21µm)	150	38	80	98.63	1114
1040	Rectangular (54µm*21µm)	150	38	60	97.59	1954
1050	rectangular (50µm*19µm)	138	35	18.50	96.22	5495
1060	rectangular (50µm*19µm)	138	35	3.45	93.70	9152
1070	rectangular (50µm*19µm)	138	35	3.05	92.88	10346
1080	rectangular (50µm*19µm)	138	35	2.74	92.06	11540
1090	rectangular (50µm*19µm)	138	35	2.48	91.23	12735
1100	rectangular (50µm*19µm)	138	35	2.27	90.41	13929
Total T	-	-	-	392.49	-	-

Al through the layer thickness, the fiber cross-sections shape, fiber perimeter, fiber equivalent diameter, porosity and S/V are substantially equal. Layers 1060, 1070, 1080, 1090 and 1100 are sintered.

-10-

The stepwise increasing S/V in function of the location in the filter
medium can be seen in curve 301 of FIGURE 3. The abscissa 31 of
FIGURE 3 is distance between the actual location in the filter to the
inflow side of the filter, expressed in mm. The ordinate 32 is the S/V
value at that location, expressed in m^2/m^3.

The metal fibers, used to provide the fiber media, are preferably
Fecralloy®-, or Aluchrome® alloy fibers. Each layer was provided as a
disc having a diameter of 168mm, and inserted in a can 1004 having a
tubular shape with an identical inner diameter.

The diesel soot particulate filter medium as given in table I, was used on
a diesel engine generating exhaust gasses comprising approximately
$30g/m^3$ soot particulate. The phase velocity of the exhaust gas through
the filter was approximately 1.5m/s.

This diesel soot particulate filter medium provided a soot filter efficiency
of more than 85% after 5 minutes of loading..

An alternative diesel soot filter medium as subject of the invention,
comprising 10 layers of fiber media, is provided in table II.

Table II

Layer number (-)	Fiber cross-section shape	Fiber perimeter (µm)	Fiber equivalent diameter (µm)	Layer thickness (mm)	Porosity (%)	S/V (m²/m³)
1010	Rectangular (54µm*21µm)	150	38	120	99.48	418
1020	Rectangular (54µm*21µm)	150	38	100	99.13	708
1030	Rectangular (54µm*21µm)	150	38	80	98.62	1121
1040	Rectangular (54µm*21µm)	150	38	60	97.69	1872
1050	Rectangular (50µm*19µm)	138	35	18.50	96.22	5495
1060	Rectangular (50µm*19µm)	138	35	2.09	89.59	15124
1070	Rectangular (50µm*19µm)	138	35	1.94	88.77	16318
1080	Rectangular (50µm*19µm)	138	35	1.8	87.94	17512
1090	Rectangular (50µm*19µm)	138	35	1.69	87.12	18707
1100	Rectangular (50µm*19µm)	138	35	1.59	86.30	19901
Total T	-	-	-	387.60	-	-

All through the layer thickness, the fiber cross-sections shape, fiber perimeter, fiber equivalent diameter, porosity and S/V are substantially equal. Layers 1060, 1070, 1080, 1090 and 1100 are sintered.

-12-

The stepwise increasing S/V in function of the location in the filter medium can be seen in curve 302 of FIGURE 3.

The metal fibers, used to provide the fiber media, are preferably Fecralloy®-, or Aluchrome® alloy fibers. Each layer was provided as a disc having a diameter of 168mm, and inserted in a can 1004 having a tubular shape with an identical inner diameter.

This diesel soot particulate filter medium provided was tested under same circumstances as the diesel soot particulate filter medium of table I. A soot filter efficiency more than 90% after a loading time of 5 minutes.

Yet an other embodiment of a diesel soot particulate filter medium as subject of the invention is given in table III. This medium comprises 17 layers of metal fibers, all preferably out of Aluchrome®, being a stainless steel alloy comprising Fe, Cr and Al.

Table III

Layer number (-)	Fiber cross-section shape	Fiber perimeter (μm)	Fiber equivalent diameter (μm)	Layer thickness (mm)	Porosity (%)	S/V (m²/m³)
1	isosceles triangle	383	77	60	99.38	244
2	Rectangular (54μm*21μm)	150	38	60	99.37	525
3	Rectangular (50μm*19μm)	138	35	15	98.56	2094
4	Rectangular (50μm*19μm)	138	35	18	98.37	2370
5	Rectangular (50μm*19μm)	138	35	17.5	97.14	4149
6	Rectangular (50μm*19μm)	138	35	18.5	96.22	5495
7	Rectangular (50μm*19μm)	138	35	5.3	93.86	8922
8	Rectangular (50μm*19μm)	138	35	3.45	93.70	9152
9	Rectangular (50μm*19μm)	138	35	3.05	92.88	10346
10	Rectangular (50μm*19μm)	138	35	2.74	92.06	11540
11	Rectangular (50μm*19μm)	138	35	2.48	91.23	12735
12	Rectangular (50μm*19μm)	138	35	2.27	90.41	13929
13	Rectangular (50μm*19μm)	138	35	2.09	89.59	15124

-14-

14	Rectangular (50µm*19µm)	138	35	1.94	88.77	16318
15	Rectangular (50µm*19µm)	138	35	1.80	87.94	17512
16	Rectangular (50µm*19µm)	138	35	1.69	87.12	18707
17	Rectangular (50µm*19µm)	138	35	1.59	86.30	19901
Total T	-	-	-	217.4	-	-

.The stepwise increasing S/V in function of the location in the filter medium can be seen in curve 303 of FIGURE 3.

An other embodiment of a diesel soot particulate filter medium 2000 as subject of the invention is shown in FIGURE 2.

A diesel soot particulate filter medium 2000, having an inflow side 2001 and an outflow side 2002 for filtration of exhaust gasses having a flow direction indicated with arrows 2003, is mounted in a filter can 2004. As an example, the thickness T indicated on FIGURE 2 by 2005, is 370mm. Over the thickness T, the S/V increases gradually from 74m²/m³ at the inflow side 2001 to 16270 m²/m³ at the outflow side 2002. The gradual increase is preferably applied according to a curve 304 as shown in FIGURE 3.

The filter is provided using stainless steel metal fibers having a rectangular cross-section with sides of 50µm and 19µm.

-15-

CLAIMS

1. A diesel soot particulate filter medium comprising fibers, said diesel soot particulate filter medium having an inflow side and an outflow side, characterized in that the filter medium thickness T between said inflow side and said outflow side being equal or more than 5cm, the S/V at said inflow side being more than 50 m^2/m^3, the S/V at said outflow side being less than 30000 m^2/m^3, and S/V increasing stepwise or gradually from said inflow side to said outflow side, wherein S being the sum of all mantle surface of the fibers present in a volume V.

2. A diesel soot particulate filter medium as in claim 1, said diesel soot particulate filter medium consists of fibers.

3. A diesel soot particulate filter medium as in any one of claims 1 to 2, said fibers being metal fibers.

4. A diesel soot particulate filter medium as in any one of claims 1 to 3, said S/V at said inflow side being less than 10000 m^2/m^3.

5. A diesel soot particulate filter medium as in any one of claims 1 to 4, said S/V at said outflow side being more than 15000 m^2/m^3.

6. A diesel soot particulate filter medium as in any one of claims 1 to 5, said diesel soot particulate filter medium comprising at least two layers of fiber media, the S/V in each layer being essentially equal over the volume of the layer.

7. A diesel soot particulate filter medium as in any one of claims 1 to 6, said filter medium having a porosity being essentially equal over the whole volume of said filter medium.

-16-

8. A diesel soot particulate filter medium as in any one of claims 1 to 6, said fibers of said filter medium having an essentially equal equivalent diameter.

9. A diesel soot particulate filter medium as in any one of claims 1 to 6, said fibers of said filter medium having an essentially equal radial cross section.

10. A diesel soot particulate filter medium as in any one of claims 1 to 9, said fibers having an equivalent diameter ranging from 0.5μm to 100μm.

11. A diesel soot filter comprising a diesel soot particulate filter medium as in any one of the proceeding claims.
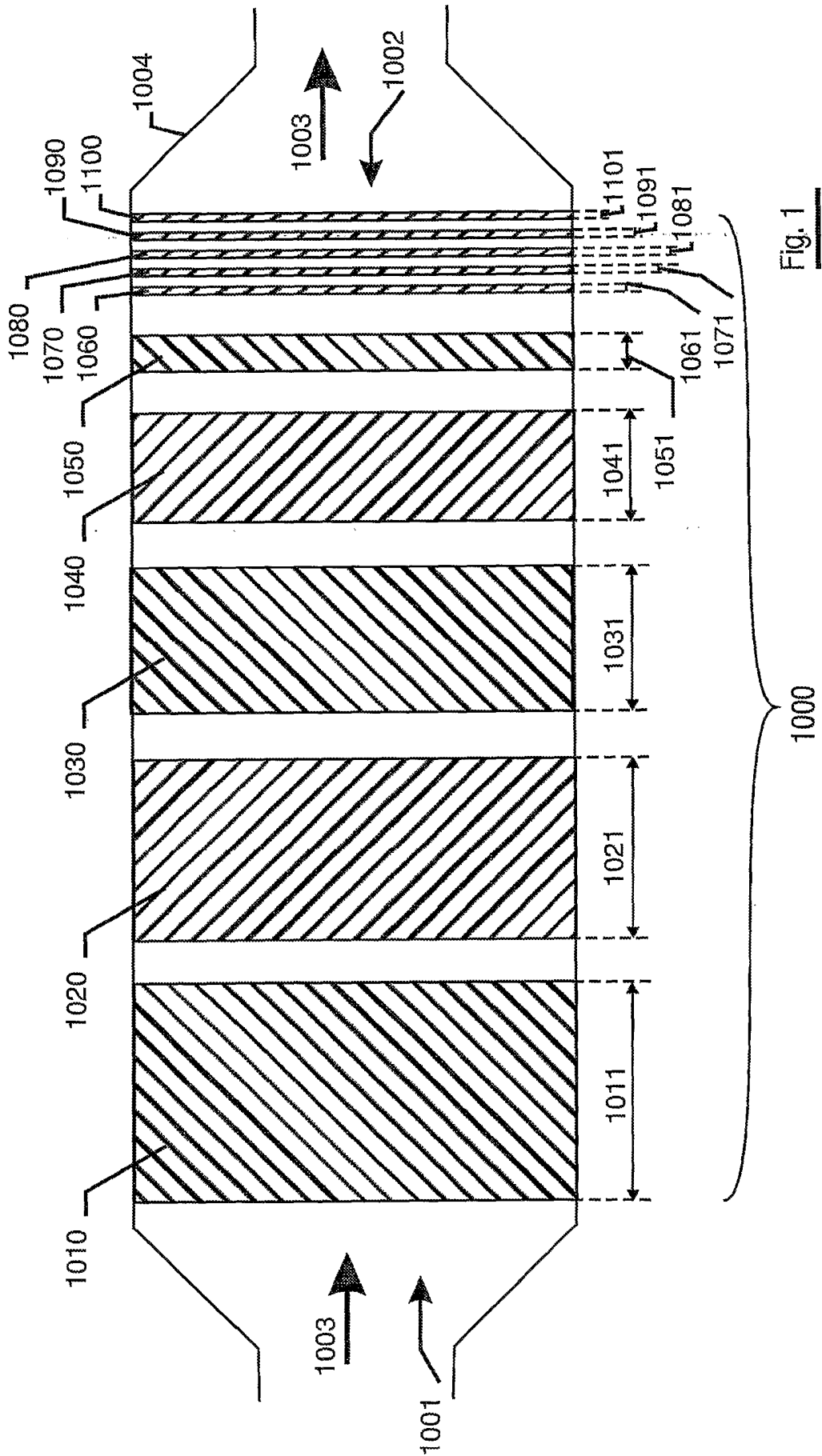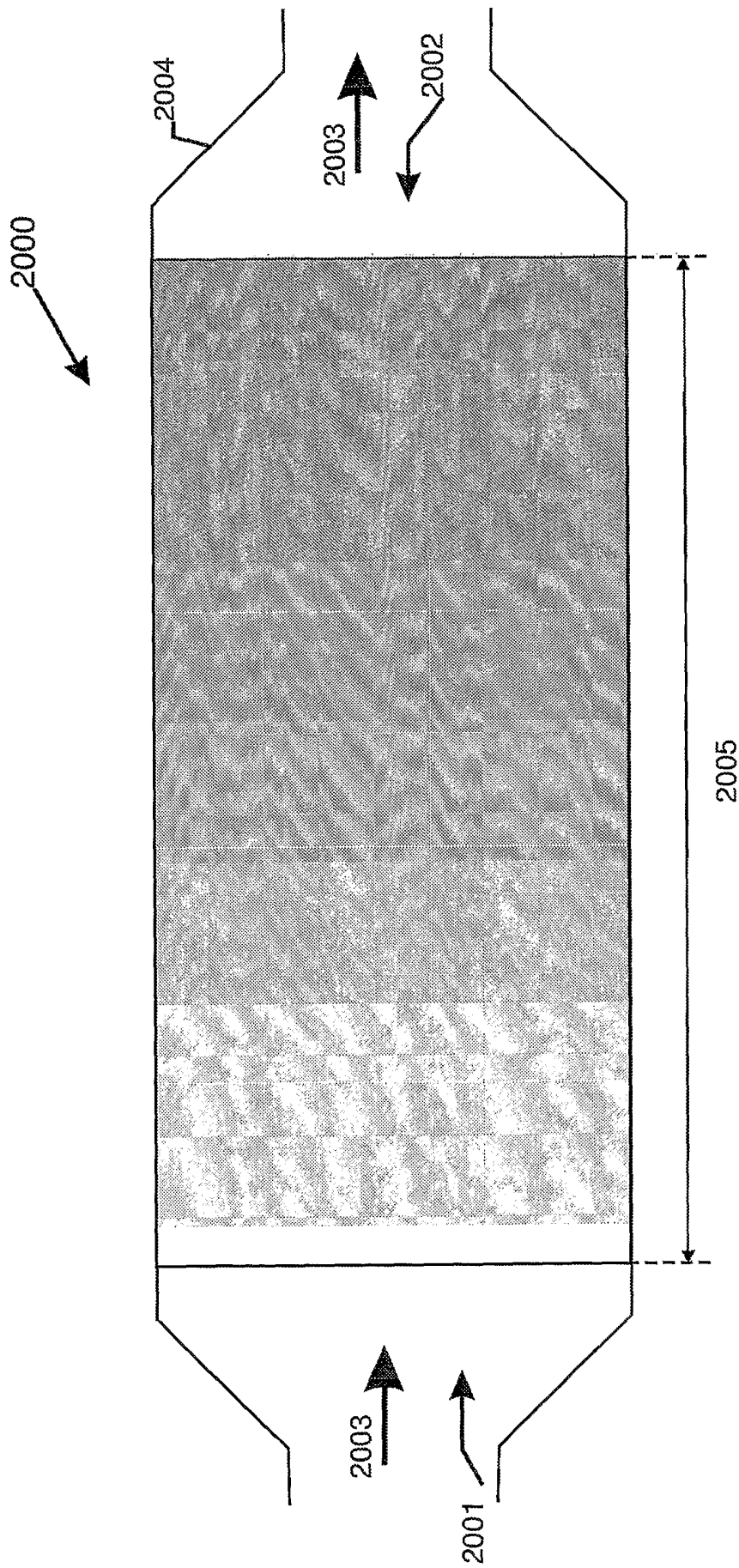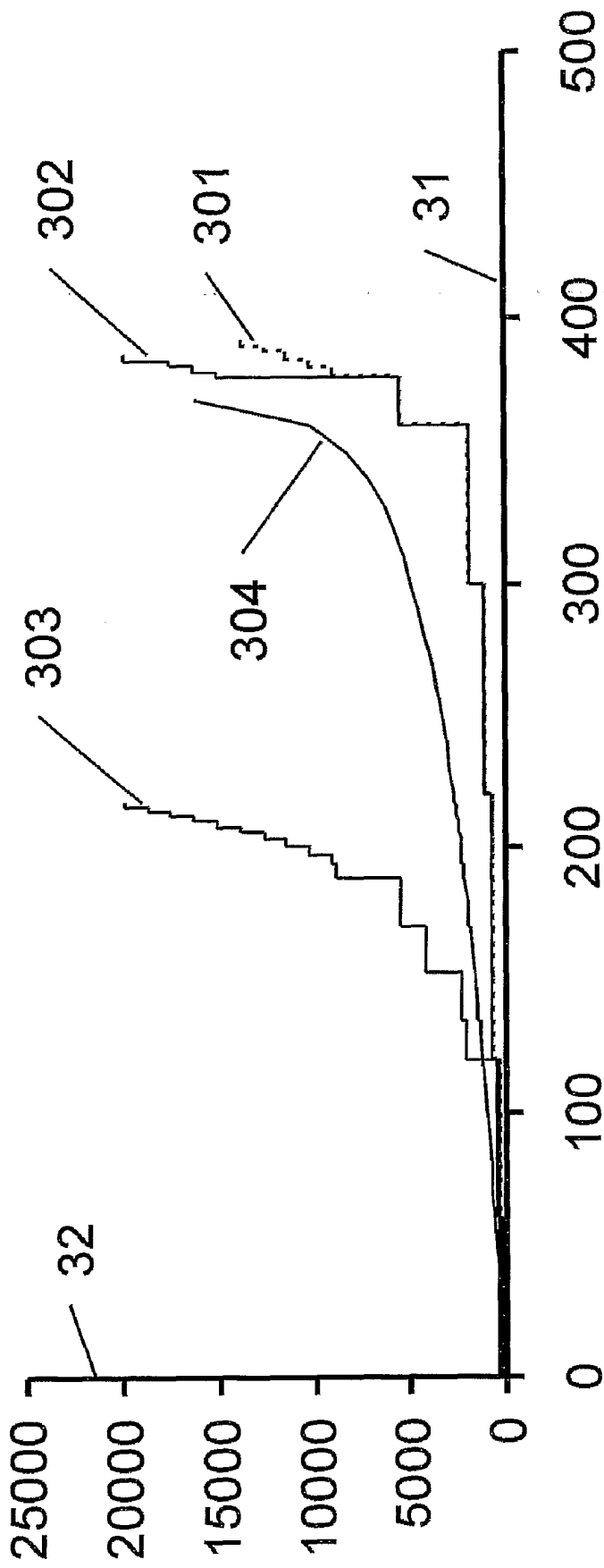
Fig. 1

Fig. 2

Fig. 3

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 03/50190

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   F01N3/022   B01D39/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   F01N   B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 2002, no. 8, 5 August 2002 (2002-08-05) & JP 2002 097924 A (ISUZU CERAMICS RES INST CO), 5 April 2002 (2002-04-05) abstract	1-3,8,9
A	WO 02/40837 A (FRAUNHOFER-GESELLSCHAFT) 23 May 2002 (2002-05-23) the whole document	1-3,6, 8-11
A	PATENT ABSTRACTS OF JAPAN vol. 2002, no. 06, 4 June 2002 (2002-06-04) & JP 2002 058939 A (HINO MOTORS LTD), 26 February 2002 (2002-02-26) cited in the application abstract	1

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| X | Further documents are listed in the continuation of box C. | | X | Patent family members are listed in annex. |

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 April 2004	21/04/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Bertram, H

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 18, no. 111, 23 February 1994 (1994-02-23) & JP 05 305207 A (FUIRUTOREESHIYON KK), 19 November 1993 (1993-11-19) abstract	1
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