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(54) **Ferromagnetic particles for magnetorheological or electrorheological fluids, magnetorheological or electrorheological fluid including these particles, and manufacturing methods**

(57) Ferromagnetic particles for magnetorheological or electrorheological fluids are carried out with a ferromagnetic material core surrounded by a shell of a polymeric material with a low specific weight. The ferromag-

netic core (2) shows a form anisotropy for the purpose of ensuring a faster alignment of the particles to the lines of force of an outer magnetic field and a greater attraction force between the particles with a consequent increase of magnetorheological effect.

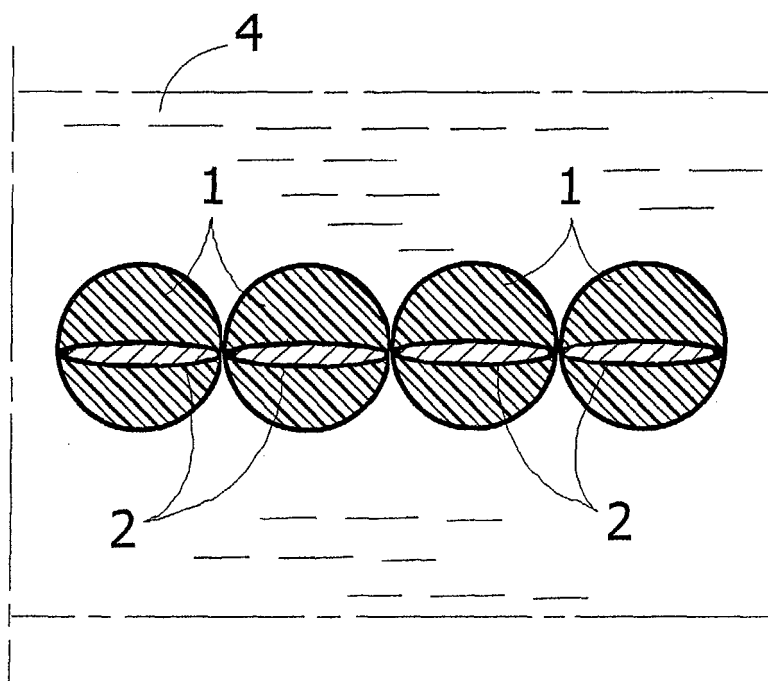


FIG. 3

Description

[0001] The present invention relates to ferromagnetic particles for magnetoreological or electrorheological fluid compositions, of the type including a carrier fluid and ferromagnetic particles dispersed in such fluid.

[0002] The magnetoreological or electrorheological fluid compositions show the essential feature of a variation of apparent viscosity when subjected to a magnetic field or to an electric field. They include ferromagnetic particles, typically with a diameter in the order of a micron, dispersed inside a carrier fluid. In the case of magnetoreological fluids, in the presence of a magnetic field the particles magnetize themselves and orientate their magnetic dipole in parallel to the lines of force of the magnetic field, organizing themselves in particle chains within the fluid. The particle chains act so as to increase the apparent viscosity or overall outflow resistance of the fluid. Without the magnetic field, the particles return in a non organized or free state and the apparent viscosity or outflow resistance of the material is reduced in a corresponding way. The electrorheological fluids have a similar behavior and respond to an electric field instead of a magnetic field.

[0003] Both the electrorheological materials and the magnetoreological materials are useful for supplying variable damping forces within such devices as dampers, impact absorption devices and elastomeric supports.

[0004] The magnetoreological or electrorheological fluid compositions known so far show, however, a drawback: the ferromagnetic particles dispersed in the carrier fluid essentially consist of pure metals or their alloys, which have by definition molecular weights greater than the carrier fluid and then show a large tendency to settle down, by compromising the behavior features of the general magnetoreological fluid.

[0005] The problem of the sedimentation may be overcome by performing a mixing of the magnetoreological fluid composition. However, this operation cannot be easily carried out when the composition is for example within a damper.

[0006] This problem has been faced in the past by changing, for example, the composition of the carrier fluid itself, namely using a high density fluid, oil. Another known solution consists in the addition to the carrier fluid of a surfactant component, which helps in keeping the ferromagnetic particles in suspension by chemical interactions. These solutions, however, are not satisfactory since, in the first case, the required viscosity difference between the active state and the passive state fails and, in the second case, the chemical bonds result of a poor entity.

[0007] For the purpose of solving such problems, the Applicant has already proposed in its Italian Patent application T02003A410 and in its corresponding International Patent application PCT/IB2003/006282 (both still confidential at the registration date of the present application) a magnetoreological fluid composition wherein

the ferromagnetic particles show a multilayer construction, with a core comprised of a first material, surrounded by a shell, formed with a second material.

[0008] In the above suggested solution, the shell of the ferromagnetic particle is formed with a ferromagnetic material, while the core is formed of a material having a specific weight lower than the carrier fluid, for example a polymeric material, and shows an empty middle cavity, if necessary.

[0009] The object of the present invention is to overcome the problem of the sedimentation above disclosed, by providing at the same time a magnetoreological or electrorheological fluid further improved with respect to the prior proposal, also from the point of view of an increase of the magnetoreological or electrorheological effect, a reduction of the response time of the fluid following to an activation thereof and a greater length of the fluid and the mechanical parts which contact therewith.

[0010] In view of attaining one or more of the aforesaid objects, the invention aims at a ferromagnetic particle for magnetoreological or electrorheological fluid compositions including a carrier fluid and ferromagnetic particles dispersed in the carrier fluid, said ferromagnetic particles having a multilayer construction, with a core of a first material, surrounded by a shell of a second material, wherein said first material forming the core is a ferromagnetic material, wherein said second material forming the shell has a specific weight lower than the first material, and wherein the core of ferromagnetic material shows a form anisotropy.

[0011] In the preferred embodiment, the ferromagnetic material core shows an elongated conformation, with a greater size and a lower size. Preferably, the greater size is substantially equal to an outer size of the particle. Always in the case of the preferred embodiment, the lower size of the ferromagnetic material core of each particle is lower than 1/4 of the greater size, and preferably is lower than 1/8 of such greater size.

[0012] Indeed, the ferromagnetic material core may be needle-shaped, or elongated ellipsoid-shaped or be needle-shaped or still simply having the form of an elongated bar.

[0013] By virtue of the above-mentioned features, and in particular thanks to the form anisotropy of the ferromagnetic core, it is possible to obtain, for instance, magnetoreological fluids showing a more effective dipole-dipole interaction between the particles on the same outer magnetic field applied. This ensures a more rapid alignment of the particles to the lines of force of the outer magnetic field, with a consequent reduction of the response times, as well as a greater attraction force between the particles, with a consequent increase of the magnetoreological effect.

[0014] Again according to the invention, the shell of the particle, which can generally be comprised of any material having a specific weight lower than the material forming the core, and preferably also lower than the carrier fluid, is made of a polymeric material. A consequence

of the narrow and elongated shape of the metal core is that the volume rate of the particle filled up by the second low specific weight material is greater, with a consequent reduction of the specific weight of the whole particle. This allows to even better contrast the tendency to sedimentation of the particles in the resting fluid. Moreover, the fact of having the outer shell of the particles made of polymeric material gives rise to further important benefits. In fact, a reduction of the abrasion phenomena of the mechanical parts contacting the fluid occurs, due to the fact that the ferromagnetic material is coated with a polymeric material. For the same reason, a reduction of the "shear thickening" phenomenon occurs as well, caused by the sub-micrometer powders produced by the rubbing of the ferromagnetic particles with each other in the solutions wherein the ferromagnetic material is exposed to the fluid.

[0015] Of course, the invention is also directed both to the ferromagnetic particles per se, as above defined, and to a magnetoreological or electrorheological fluid including such particles.

[0016] Finally, the invention also relates to a method for the production of ferromagnetic particles for magnetoreological or electrorheological fluid compositions, which includes the step of forming a plurality of cores of ferromagnetic material having an elongated conformation, with a greater size and a lower size, and the step of forming around each core a shell of a material having a specific weight lower than the material constituting the core. The ferromagnetic material cores may be, for example, carried out by chemical synthesis or through extrusion and/or drawing of a continuous wire and subdivision thereof by following cuts in a plurality of elongated bars. The shell may be carried out around each core through an emulsion polymerization step. Alternatively, it can be forecast a co-extrusion method of a metal and the polymeric material, which gives rise to the formation of an elongated wire with a ferromagnetic inner core and a polymeric shell, after which one proceeds through cut operations following to the division of the multilayer wire thus obtained in a plurality of elongated multilayer bars. In this case, the whole particle takes the form of an elongated bar.

[0017] Further features and advantages of the invention will result from the following description with reference to the enclosed drawings, which are given by mere way of not limitative example, wherein:

- figure 1 is a diagrammatic sectional view of a ferromagnetic particle according to the invention,
- figures 2, 3 show a plurality of particles according to the invention in the resting condition and in the active condition, respectively, of the magnetoreological fluid, and
- figures 4, 5 and 6 diagrammatically show three different methods for obtaining the ferromagnetic particles according to the invention.

[0018] Figure 1 shows, by way of example, a preferred embodiment of a ferromagnetic particle according to the invention. The particle, generally shown with numeral 1, includes a core 2 of ferromagnetic material, preferably consisting in low coercivity ferromagnetic material (that is, activable with a low magnetic field), such as, for example, iron, cobalt, nickel or their alloys. The ferromagnetic core 2 is acicular or needle-shaped, or elongated ellipsoid-shaped, with a longitudinal axis 2a and a cross section with a circular shape. More generally, the core 2 may have any elongated shape with a greater size L, and a lower size d. For instance, the core 2 could be, instead of being elongated ellipsoid- or needle-shaped, elongated bar-shaped with a circular or quadrangular or polygonal section.

[0019] Preferably, the lower size d is lesser than 1/4 of the greater size L. Still preferably, the lower size is lesser than 1/8 of the greater size L.

[0020] The ferromagnetic core 2 is surrounded by a shell 3 consisting in a material having a specific weight lower than the ferromagnetic material forming the core 2. Preferably, the material forming the shell 3 has a specific weight also lower than the specific weight of the carrier fluid wherein the particles according to the invention are intended to be dispersed. In the preferred embodiment, the material forming the shell 3 is a polymeric material. Generally, it can be selected from the group consisting in polymeric foams, microporous polymers, glass, aluminosilicates.

[0021] The specific weight of the material comprising the shell 3 is preferably lower than 1 g/cm³.

[0022] Always in the event of the preferred embodiment shown, the shell 3 is obtained in such a way to impart to the particle an overall substantially spherical or slightly ellipsoidal shape. In the shown example, further, the greater size L of the metal core 2 substantially corresponds with the outer size of the particle 1, in this case therefore with the diameter of the particle 1.

[0023] The narrow and elongated shape of the metal core 2 permits to obtain different advantages. First of all, because of the particular conformation of the core 2, the total volume rate of the particle 1 filled up by the low specific weight material 3 is high, which allows to reduce to a minimum the tendency of the particles to settle down when they are dispersed in a resting condition fluid. Moreover, the above described conformation of the core 2 imparts to such core a form anisotropy which renders more effective the dipole-dipole interaction between the particles on the same outer magnetic field applied. This ensures a more rapid alignment of the particles to the lines of force of the magnetic field. Figure 2 of the enclosed drawings shows a plurality of particles 1 dispersed in a fluid in a resting condition, and figure 2 shows the particles in the aligned condition wherein they arrange following to the application of a magnetic field H. In figures 2, 3 the numeral 4 is the fluid wherein the particles 1 are dispersed. The magnetoreological fluid according to the invention therefore shows a reduced response time fol-

lowing to its activation. A further advantage lies in a greater attraction force between the particles with a consequent increase of the magnetoreological effect.

[0024] The predisposition of an outer shell of polymeric material further gives rise to the additional benefits which have already been above disclosed: reduction of the abrasion phenomena of the mechanical parts contacting the fluid and reduction of the "shear thickening" phenomenon caused by the sub-micrometer powders produced by the rubbing of the ferromagnetic particles with each other, by virtue of the protective action exerted by the polymeric material which covers them.

[0025] With reference to figure 4, the ferromagnetic particles can be obtained by carrying out, at first, the acicular metal cores 2 through chemical synthesis and by carrying out, secondly, the shell 3 by emulsion polymerization.

[0026] According to a variation (figure 5), the metal cores 2 are obtained in a form of an elongated bar by means of an extrusion operation and/or continuous wire drawing 20 which is then subdivided through following cuts executed by a cutting tool 21.

[0027] Figure 6 relates to a further alternative method, wherein a co-extrusion method of the metal and the polymer is carried out by a co-extrusion device 22 which allows to obtain a continuous wire 23 having a metal core coated with a shell of polymeric material, which is then subdivided by a cutting tool 21 in a plurality of short bars 1, forming the ferromagnetic particles according to the invention. In this case, each particle has an overall conformation in the form of an elongated bar with a ferromagnetic core.

[0028] Obviously, further without prejudice to the principle of the invention, construction details and embodiments could widely vary with respect to what has been described and shown by mere way of example, without leaving the ambit of the present invention.

[0029] In particular, the ferromagnetic particle according to the invention is usable both for carrying out magnetoreological fluids and for carrying out electrorheological fluids.

Claims

1. Ferromagnetic particle for magnetoreological or electrorheological fluid compositions including a carrier fluid (4) and ferromagnetic particles (1) dispersed in the carrier fluid (4), said ferromagnetic particles having a multilayer structure, with a core (2) of a first material, surrounded by a shell (3) of a second material, wherein said first material forming the core (2) is a ferromagnetic material, wherein said second material forming the shell (3) has a specific weight lower than the first material (2), wherein the core (2) of ferromagnetic material shows a form anisotropy.

2. Ferromagnetic particle according to claim 1, **characterized in that** the core (2) of ferromagnetic material has an elongated conformation, with a greater size (L) and a lower size (d).

3. Ferromagnetic particle according to claim 1, **characterized in that** the greater size (L) of the core (2) is substantially equal to an outer size of the particle (1), which can be spherical- or slightly ellipsoidal-shaped.

4. Ferromagnetic particle according to claim 2, **characterized in that** the lower size (d) of the core is lesser than 1/4 of the greater size (L), and preferably is lesser than 1/8 of the greater size.

5. Ferromagnetic particle according to claim 4, **characterized in that** the core (2) has a form of an elongated ellipsoid.

6. Ferromagnetic particle according to claim 4, **characterized in that** the core (2) has a form of an elongated bar.

7. Ferromagnetic particle according to claim 1, wherein the first material is a low coercivity ferromagnetic material.

8. Ferromagnetic particle according to claim 7, wherein the ferromagnetic material is selected among iron, cobalt, nickel and their alloys.

9. Ferromagnetic particle according to claim 1, **characterized in that** the second material is selected from a group consisting in polymeric substances, glass, aluminosilicates.

10. Ferromagnetic particle according to claim 9, **characterized in that** the second material with a low specific weight is selected among polymeric foams and micro-porous polymers.

11. Ferromagnetic particle according to claim 1, **characterized in that** said second material has a specific weight lower than 1 g/cm³.

12. Magnetoreological or electrorheological fluid composition, including a carrier fluid and ferromagnetic particles according to one or more of the preceding claims.

13. Method for the manufacturing of ferromagnetic particles according to one or more of claims 1-11, **characterized in that** it includes a step of obtaining a core (2) of ferromagnetic material having a form anisotropy, and a following step of obtaining a shell (3), consisting in a material having a specific weight lower than the material forming the core (2), above said

core (2).

14. Method according to claim 13, **characterized in that** the ferromagnetic core (2) is obtained by chemical synthesis. 5
15. Method according to claim 14, **characterized in that** the cores (2) of the ferromagnetic particles are obtained through following cuts of a continuous wire obtained by extrusion and/or drawing. 10
16. Method according to claim 13, **characterized in that** a continuous wire, having a ferromagnetic material core surrounded by a shell, is obtained through a co-extrusion method, and **in that** such continuous wire is divided through following cutting operations in a plurality of ferromagnetic particles (1) each having an elongated bar conformation. 15

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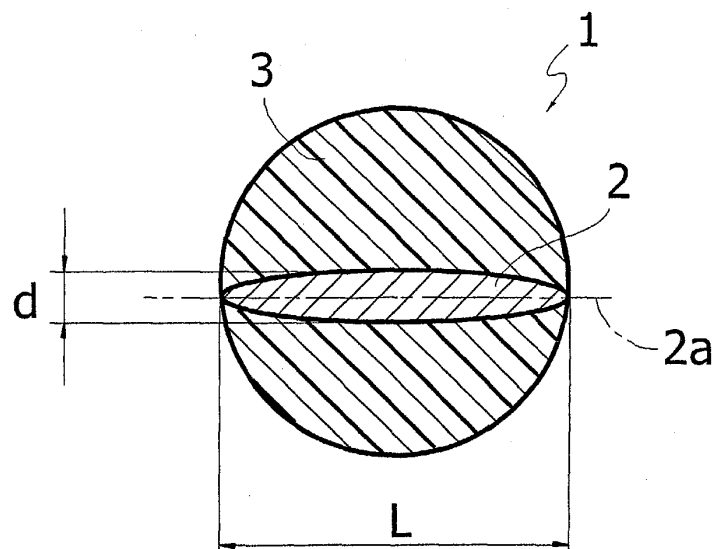


FIG. 1

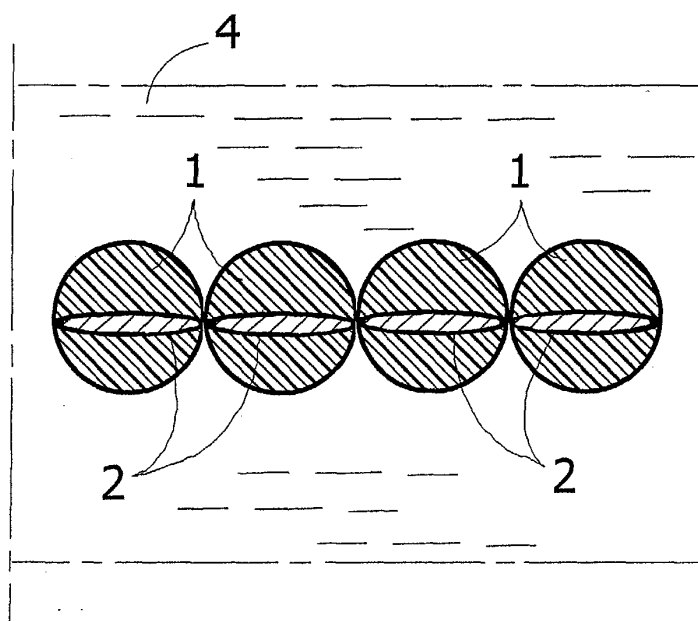
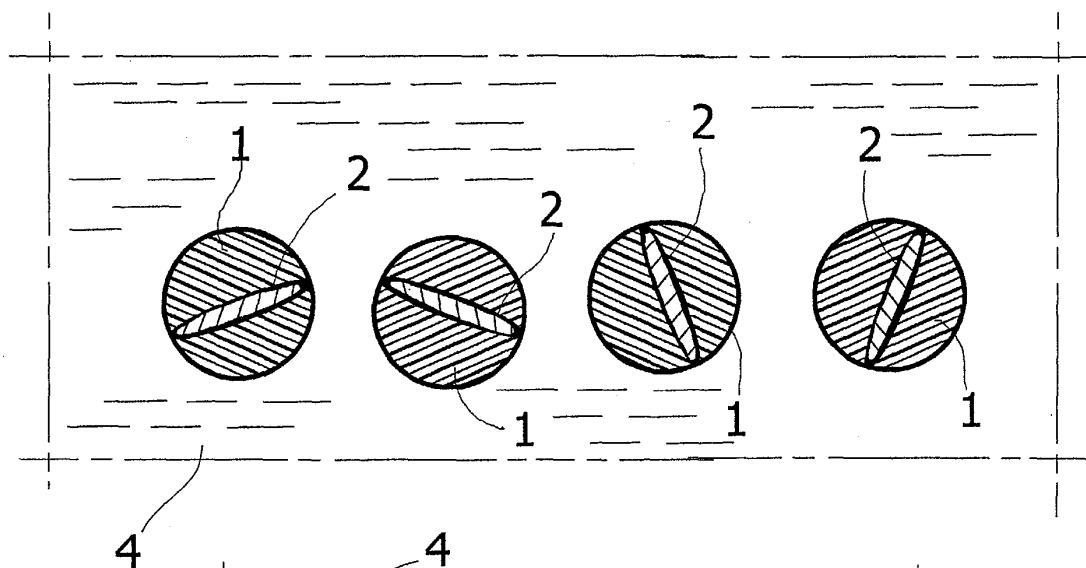


FIG. 3

FIG. 4

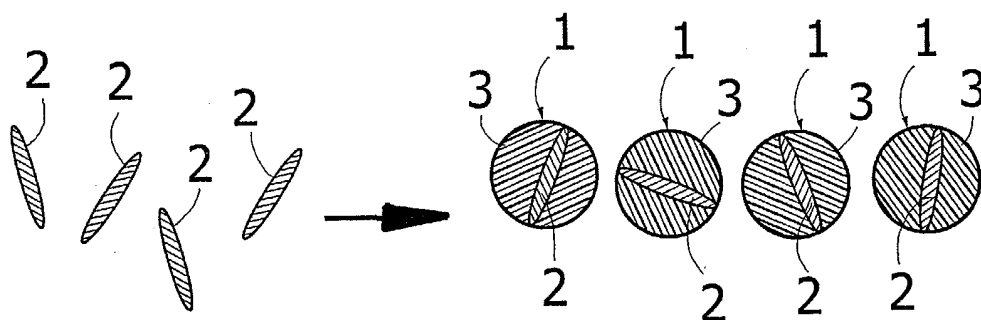


FIG. 5

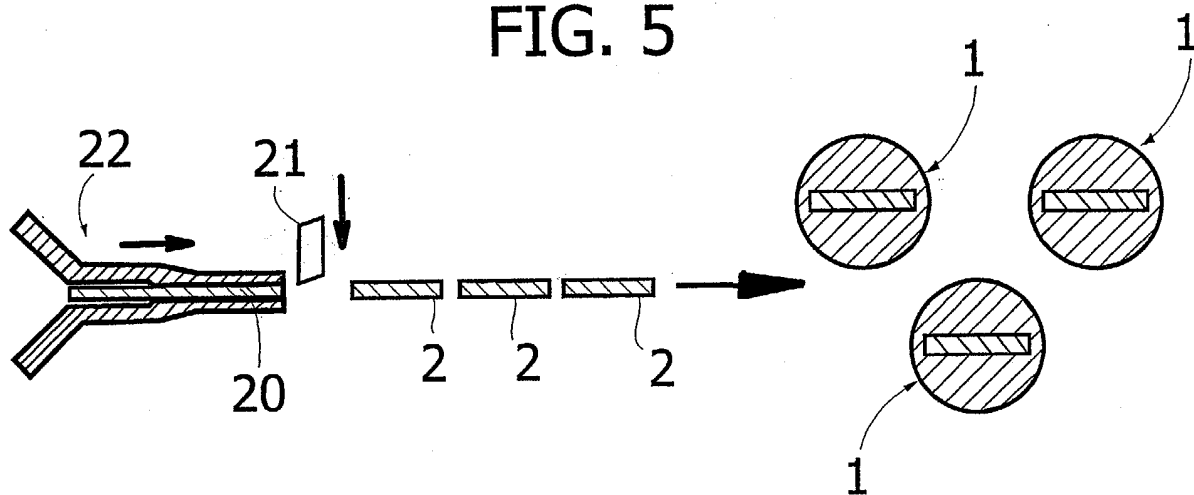
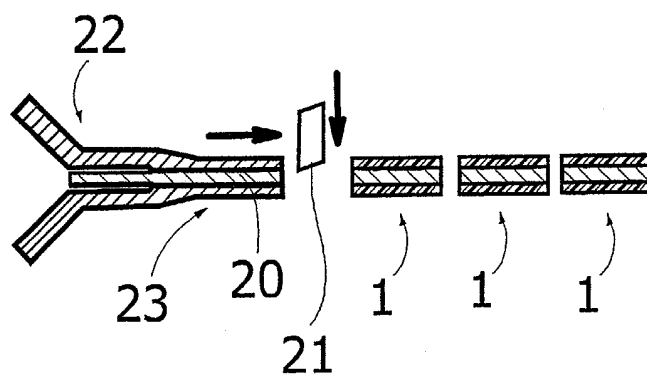


FIG. 6





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Application Number
EP 04 42 5669

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Place of search Munich		Date of completion of the search 24 January 2005	Examiner Reder, M
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EUROPEAN SEARCH REPORT

Application Number
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