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(54) ELECTROMAGNETIC INDUCTION ELECTRIC HEATER FOR FLUIDS

(57) Heater for electromagnetic induction fluids (100), comprising:
- a coil (1) crossed by an alternating electric current for the generation of an electromagnetic field,
- a container (2), arranged inside the electromagnetic induction coil, consisting of a hollow cylindrical element made of non-magnetic electrically non-conductive material, containing inside it a heating element (3), in the area in which the coil induces the electromagnetic field,
- two perforated flanges (5) for closing the container (2) provided with connections for the passage of the fluid,
- a thermal insulation (6) between the coil (1) and the container (2) made of an electrically non-conductive and non-magnetic material,
- in which the heating element (3) consists of a set of balls (4), having a core (4 ") of electrically conductive material and an outer coating (4 ’) of electrically insulating material.

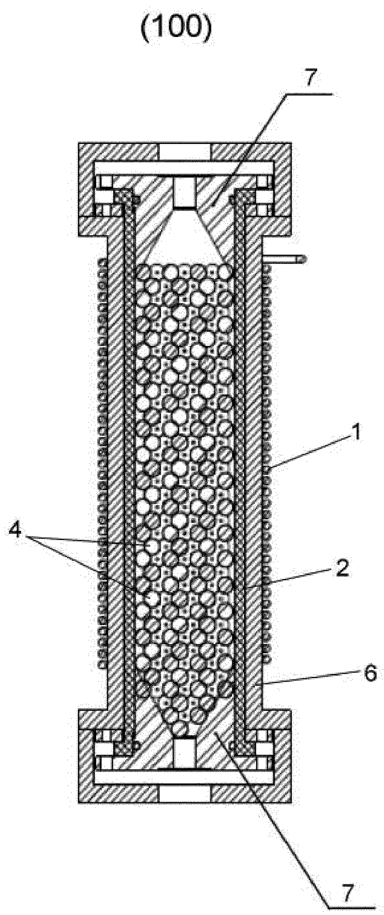

FIG.4

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Description

[0001] The present invention relates to an electromagnetic induction electric heater for fluids.

State of art

[0002] Electric heaters for electromagnetic induction fluids are a category of electric heaters for fluids that use the heat produced by Joule effect by parasitic currents induced in a conductive material by an electromagnetic field generated by one or more coils in which a variable current flows.

[0003] The variable magnetic field is induced by the oscillating currents that travel the coils; the currents are produced by generators not shown in the accompanying figures, and whose description is not relevant for the purposes of the invention.

[0004] Unlike the resistive heaters where the heat is produced in the conductor and propagates towards the fluid to be heated through the heating element envelope, in the electromagnetic induction heaters the heat is not produced in the conductor that generates the electromagnetic field but in a material in direct contact with the fluid to be heated.

[0005] In the patent US 4602140 a solution is described in which the fluid circulates in a pipe which constitutes the secondary winding of a transformer; in this way the currents induced in the secondary circuit by the electromagnetic field produced by the primary circuit generate a loss due to Joule effect in the tube and consequently they lead to the heating of the fluid. This solution, having to insert the fluid circuit inside a magnetic circuit on which the coils of the primary circuit are housed, has some drawbacks which determine a limited field of application:

1. in the case of high fluid flow rates, a high number of tubes must be used, which increases the size of the heater;
2. in order to obtain a high efficiency of the heater it is necessary to limit the losses in the magnetic circuit and consequently low loss and high cost materials must be used;
3. to improve the heat exchange between the pipe wall and the fluid it is necessary to increase the exchange surface by reducing the diameter of the tube and increasing the number of tubes; this entails a greater complexity of construction and a non-competitiveness of the heater compared with resistive electric heaters;
4. in the case of high viscosity fluids it is necessary to add mixing systems inside the tubes that artificially increase the mixing of the fluid and avoid the establishment of a laminar flow which would cause a thermal gradient in the fluid between the wall and the center of the tube.

[0006] US 6118111 overcomes some limitations of the previous solution. In this patent the tube bundle is replaced by an assembly consisting of two concentric tubes of non-conductive material which delimit an annular chamber inside which a cylindrical corrugated element of a conductive material is housed, the function of which is to realize the single turn coil of the secondary circuit where heat is generated. The limitation of this solution is linked to the small exchange surface between the fluid and the heating element, consisting solely of the inner and outer surface of the corrugated cylindrical element. To increase the exchange surface it is necessary to increase the diameter of the heating element and consequently also the dimensions of the magnetic circuit in which the assembly is contained.

[0007] WO 89/12204 discloses a solution that improves the ratio between the size of the heating unit and the heat exchange surface. In this patent the coil of the secondary circuit, with the function of heating element consists of a spiral crossed by the fluid from the external turn towards the internal part (or vice versa), therefore in this solution the exchange surface is increased with the same volume occupied. For this patent also there is the limitation of being able to operate with high viscosity fluids due to the laminar flow that is established in the spiral.

[0008] Many of the previous limitations are overcome by EP0873045A1. This patent describes a heater consisting of a tube of non-conductive material surrounded by a cylindrical coil adapted to generate a field within the heater's tube. The heating element consists of a matrix of interconnected plates in such a way as to form an element capable of being crossed by parasitic electric currents and at the same time to realize a structure capable of having a high exchange surface per unit of volume and to generate a mixing and a turbulent motion of the fluid passing through it. This solution, despite overcoming the limitations of the previous solutions, has some limitations:

1. the external diameter of the heating element must be limited, since the eddy currents tend to travel the outer periphery (skin effect) and consequently if the diameter increases, the specific power decreases going from the periphery towards the center of the heater;
2. the cost of the heating element, due to the complex geometry and construction structure, is high;
3. the heating element is specific for a given diameter of the heater tube and has no modular characteristics;
4. to create high power units due to the limitation on the diameter it is necessary to put more units in parallel.

Object of the invention

[0009] The object of the invention is to eliminate the drawbacks and problems of the different solutions of the prior art illustrated above.

[0010] In particular, an object of the invention is to provide an electromagnetic induction heater which allows to obtain high specific powers without geometric limitations.

[0011] Another object of the invention is to provide such a heater for electromagnetic induction fluids in which there is a high heat exchange surface per unit of volume.

[0012] Another object of the invention is to provide such a heater for electromagnetic induction fluids in which there is high mixing without stagnation points, which can also be used with high viscosity fluids without adopting complex heater geometries.

[0013] Another object of the invention is to provide such a heater for electromagnetic induction fluids in which the greatest modularity and scalability is obtained.

[0014] Another and not the last object of the invention is to provide such a heater for electromagnetic induction fluids which is simple to make, therefore economical, and at the same time extremely reliable.

[0015] These objects are achieved by the heater for electromagnetic induction fluids according to the invention which presents the characteristics of the appended independent claim 1.

[0016] Advantageous embodiments of the invention appear from the dependent claims.

[0017] Substantially, the heater for electromagnetic induction fluids according to the invention comprises:

- a coil crossed by an alternating electric current for the generation of an electromagnetic field,
- a container, arranged inside the electromagnetic induction coil, consisting of a hollow cylindrical element made of non-magnetic electrically non-conductive material, containing inside it a heating element, in the area in which the coil induces the electromagnetic field,
- two perforated closing flanges of the container provided with connections for the passage of the fluid,
- a thermal insulation between the coil and the container, made of an electrically non-conductive and non-magnetic material,

wherein the heating element consists of a set of spheres, having a core of electrically conductive material and an external coating of electrically insulating material.

Brief description of the figures

[0018] Further characteristics of the invention will be made clearer by the detailed description that follows, referring to purely exemplary and therefore non-limiting embodiments thereof, illustrated in the appended drawings, in which:

- Fig. 1 is a mid cross sectional view of a heater according to the invention;
- Fig. 2 is an axonometric view of the ball-bed heating element;
- Fig. 3 is a cross sectional view of a sphere which constitutes the heating element;
- Fig. 4 is a cross sectional view of a heater equipped with end flanges shaped to eliminate stagnation of liquid inside it.

Description of preferred embodiments

[0019] With reference to the accompanying figures, and for now in particular to Figure 1, an electromagnetic induction heater according to the invention is shown in section, generally indicated by the reference number (100).

[0020] The heater (100) substantially consists of a coil 1 crossed by an alternating electric current for generating an electromagnetic field, a hollow cylindrical container 2 made of an electrically non-conductive and non-magnetic material, compatible with the fluid to be heated, and a heating element 3 consisting of a set of balls 4 of conductive material coated with an electrically insulating layer compatible with the fluid to be heated. Said spheres fill the cavity of the container according to an ordered or random packing.

[0021] The container 2 is arranged inside the coil 1 and is closed at its ends by two flanged flanges 5, of perforated cylindrical shape, provided with hydraulic connections for the fluid inlet and outlet respectively.

[0022] Outside the container 2 there is a layer of thermally insulating and electrically non-conductive material 6, whose function is to avoid the heat dissipation of the heater and to avoid heating the electromagnetic induction coil 1 by the container.

[0023] The variable electromagnetic field produced by the induction coil 1 generates in the spheres 4 parasitic currents which due to Joule effect determine the heating of the spheres 4. The fluid to be heated passes through the ball bed of the heating element 3 heating by conduction and convection.

[0024] Since the spheres 4 are electrically isolated from each other, the resulting parasitic currents cannot circulate in a continuous electric circuit on the periphery of the heating element 3, therefore the skin effect typical of the electromagnetic induction processes can occur only within the single sphere 4. In this way the shielding effect on the central part of the heating element 3 produced by the currents which, due to the skin effect, circulate on the surface of a continuous matrix heating element is avoided, and consequently a greater uniformity of the power density is obtained. in the whole body of the heating element 3.

[0025] Figure 2 shows the ball bed heating element 3 which ensures excellent mixing of the fluid even in the case of very viscous fluids without stagnation points. The size of the balls 4 can be optimized according to the specific flow rate and the viscosity of the fluid that passes through the heating element 3 and the dimensions of the container 2.

[0026] In particular, balls of increasing diameter are used as viscosity and/or flow rate increase(s).

[0027] The ball bed heating element 3 comprises a simple constructive solution that can be scaled over a wide range of powers that does not require the construction of complex geometry elements.

[0028] Figure 3 shows in cross section one of the spheres which constitute the heating element 3. The electrically insulating outer layer 4 'covers the internal part in conductive material 4' '. The conductive material 4 " of the core of the spheres 4 may have diamagnetic, paramagnetic or ferromagnetic characteristics. The 4 " core of the balls 4 can be full or hollow.

[0029] The electrically insulating coating of the balls 4 can consist of thermoplastic or thermosetting resin in the case of heaters with operating temperatures up to 200 ° C; for higher temperatures the coating may be of the ceramic type. The choice of electrically insulating coating must be made according to the maximum operating temperature and to the chemical compatibility with the fluid to be heated.

[0030] Figure 4 shows in section an alternative constructive solution of the heater (100) in which the internal configuration of the flanges 5 is funnel-shaped to prevent the formation of stagnation of the fluid that travels the electromagnetic induction heater from top to bottom with reference to the figure. This solution is particularly suitable for high viscosity fluids, pastes and creams.

[0031] In the foregoing description we have spoken of spheres 4, constituting the heating element 3. It is however evident that instead of the spheres 4 roundish bodies may be used not necessarily with all the points of the surface at the same distance from a center, or even filling bodies of another form.

[0032] Naturally, the invention is not limited to the particular embodiments previously described and illustrated in the accompanying drawings, but numerous detail modifications can be made to it, within the reach of a person skilled in the art, falling within the scope of the invention defined by the attached claims.

Claims

1. Electromagnetic induction fluid heater (100), comprising:

- a coil (1) crossed by an alternating electric current for the generation of an electromagnetic field,
- a container (2), arranged inside the electromagnetic induction coil, consisting of a hollow cylindrical element made of non-magnetic electrically non-conductive material, containing inside it a heating element (3), in the area in which the coil induces the electromagnetic field,
- two perforated flanges (5) for closing the container (2) provided with connections for the passage of the fluid,
- a thermal insulation (6) between the coil (1) and the container (2) made of electrically non-conductive and non-magnetic material,

characterized in that:

- the heating element (3) consists of a set of balls (4), having a core (4 ") of electrically conductive material and an outer coating (4 ') of electrically insulating material.

2. Electromagnetic induction fluids heater (100) according to claim 1, wherein said set of balls (4) constituting the heating element (3) are randomly or orderly packed.

3. Electromagnetic induction fluids heater (100) according to claim 1 or 2, **characterized in that** said conductive core (4 ") of the balls (4) is made of a material having diamagnetic, paramagnetic or ferromagnetic characteristics.

4. Electromagnetic induction fluids heater (100) according to any one of the preceding claims, **characterized in that** the conductive core (4 ") of the balls (4) has a solid or hollow structure.

5. Electromagnetic induction fluids heater (100) according to any of the previous claims, **characterized in that** the diameter of the balls is an increasing function of the viscosity of the fluid passing through them.

6. Electromagnetic induction fluids heater (100) according to any one of the previous claims, **characterized in that** at least one of said end flanges (5), arranged on the fluid outlet side, has an internal funnel-like shape to prevent the formation of stagnation of the fluid that runs through the electromagnetic induction heater.

7. Electromagnetic induction fluids heater (100) according to any of the previous claims, **characterized in that** the balls (4) which constitute the heating element (3) are covered by a layer of insulating material made of a thermoplastic or thermosetting resin.

8. Electromagnetic induction fluids heater (100) according to any one of the claims from 1 to 6, **characterized in that** the balls (4) which constitute the heating element (3) are coated with a layer of ceramic material.

9. Method for heating fluids consisting in passing the fluid into an electromagnetic induction heater (100) comprising a heating element (3) consisting of a set of balls (4), having a core (4 ") of electrically conductive material and an outer coating (4 ') of electrically insulating material, according to any one of the previous claims.

(100)

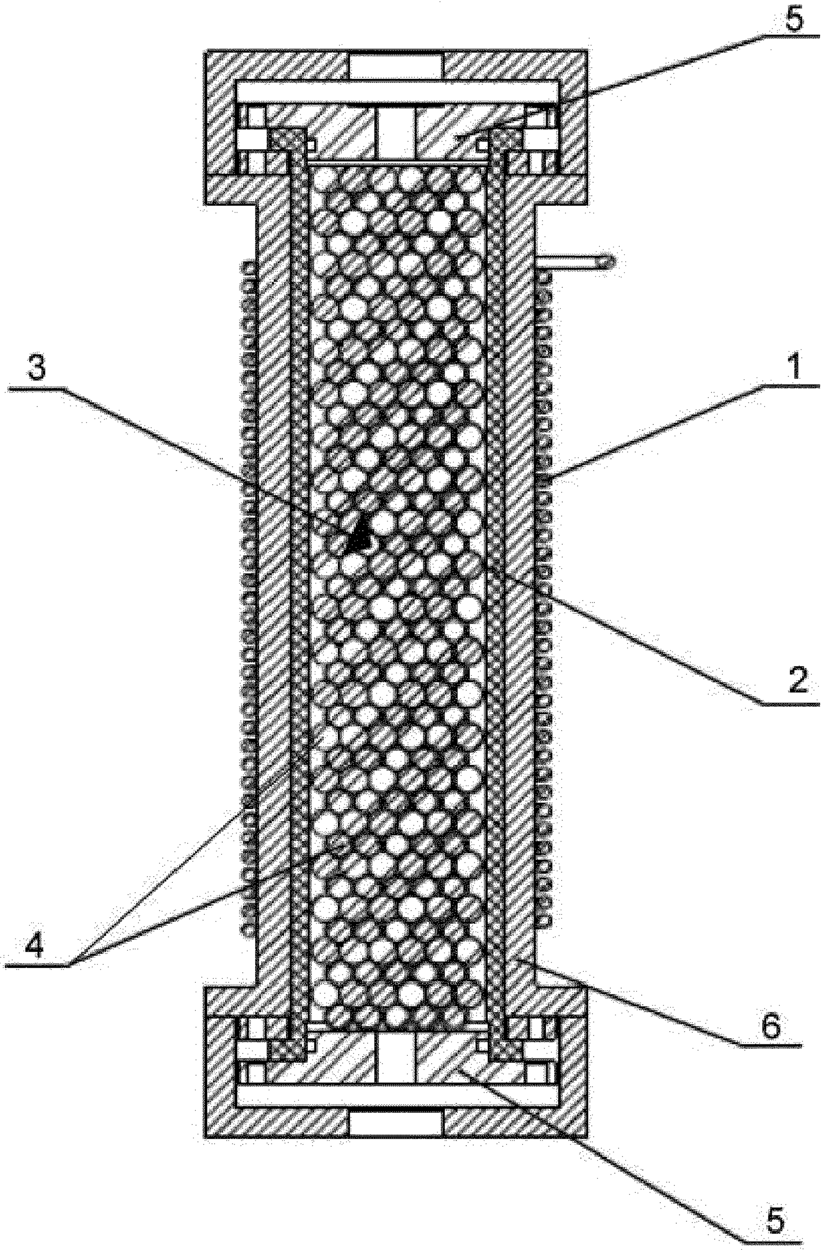

FIG.1

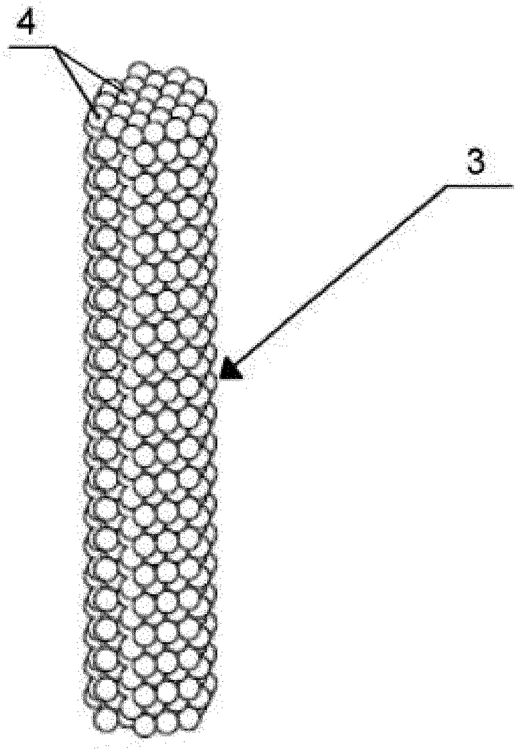

FIG.2

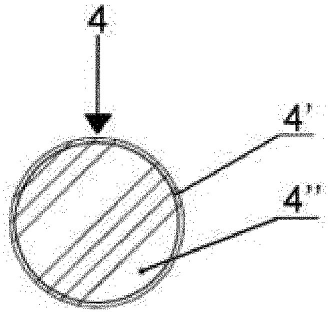

FIG.3

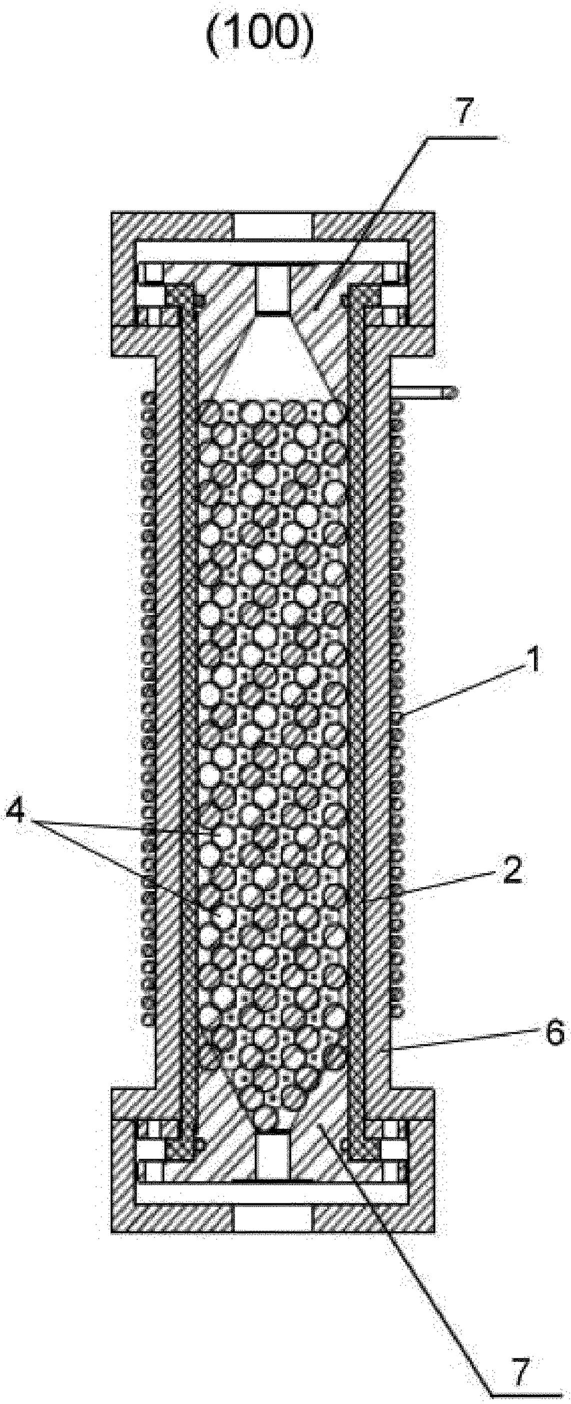

FIG.4

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EUROPEAN SEARCH REPORT

Application Number
EP 19 15 6774

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	19 June 2019	Aubry, Sandrine

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