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(54) SYSTEM FOR TREATING FLUIDS

(57) A system for treating fluids, in particular for treating hydrocarbon fuel, is provided. The system comprises one or more cavitation treatment stages, each of the one or more cavitation treatment stages configured to create a mixture of a first fluid and a second fluid, and generate vapor-filled cavities embedded in the mixture; the system further comprising one or more resonance frequency treatment stages, each of the one or more resonance frequency treatment stages configured to increase the amount of gaseous content in the vapor-filled cavities by resonance being introduced into the mixture. Further, a system for providing treated fluid to an engine apparatus and a method for treating fluids are provided.

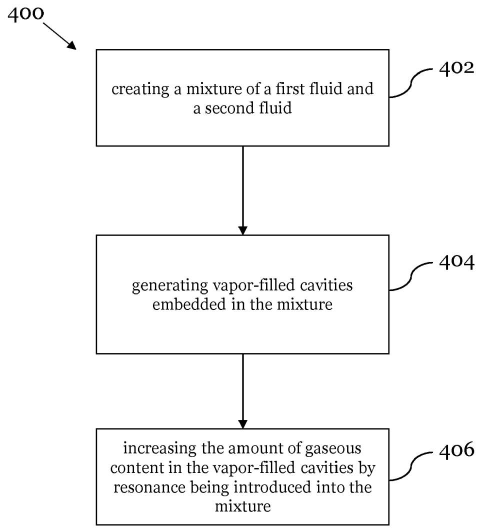

Fig. 4

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Description

[0001] The present patent application relates to systems and methods for treating fluids, in particular hydrocarbon fuel and water, wherein the treatment increases the amount of gaseous content in a mixture of the fluid, in particular in an emulsified hydrocarbon fuel.

[0002] Power units on the basis of internal combustion engines are a main contributor to carbon emissions that accelerate global warming and thereby impact the environment and the air quality, because they combust hydrocarbon fuels which causes emissions such as particulate matter (PM), hydrocarbon (HC), carbon dioxides (CO_2), carbon monoxides (CO), and nitrogen oxides (NOX).

[0003] Replacing hydrocarbon fuels with alternatives like biofuels, synthetic fuels or even burning hydrogen gas in combustion engines each have drawbacks like limited availability, high costs, difficult storage or handling and in the end often require costly and elaborate modifications to the combustion engine itself.

[0004] Accordingly, while the search for sustainable and green power units and alternative fuels is ongoing, well-established internal combustion engines that run on hydrocarbon fuels will remain to be irreplaceable in a lot of applications - one of these applications being marine two-stroke internal combustion engines.

[0005] In order to achieve a short-term or medium-term reduction of carbon gas emissions in established internal combustion engines, it is important to improve the combustion of hydrocarbon fuels in internal combustion engines.

[0006] Water-emulsified hydrocarbon fuels have emerged to be a promising improvement to the process of burning hydrocarbon fuels in conventional internal combustion engines. Water-emulsified hydrocarbon fuels are emulsions of liquid hydrocarbon fuels and water (H_2O). The emulsion represents a dispersion, i.e. a heterogeneous mixture of two substances that hardly dissolve in each other. In a water-emulsified hydrocarbon fuel, hydrocarbon fuel represents the continuous phase of the dispersion, while a disperse phase of water is distributed in said continuous phase. Based on the temperature and pressure conditions, a water-emulsified hydrocarbon fuel may be represented by an emulsion of liquid water contents distributed within the liquid fuel or a foam having water vapor distributed within the liquid hydrocarbon fuel.

[0007] Today, emulsified fuels are used by performing direct water injection into the cylinders of an internal combustion engine. This decreases the combustion temperature and reduces NOX emissions, but not only requires modification of the engine itself, it also adversely affects the stability of the system as adding water can lead to corrosion and other problems.

[0008] These drawbacks are often addressed by adding additives to keep the emulsion stable. These additives, however, again increase the environmental impact of the combustion, because of combustion products that are generated when the additives are burned.

[0009] Hence, there is a need in the art for improving the treatment of water-emulsified hydrocarbon fuels.

[0010] This need is fulfilled by a system for treating fluids, in particular hydrocarbon fuel, according to the presented invention. A system for treating fluids according to the present invention comprises one or more cavitation treatment stages and one or more resonance frequency treatment stages. The one or more cavitation treatment stages and the one or more resonance frequency treatment stages may be distinct components of the system that may be connected in series or, in some embodiments of the invention, the cavitation treatment and the resonance frequency treatment may be interleaved, i.e. performed by a component of the system that combines the cavitation treatment stage and the resonance frequency treatment stage.

[0011] A cavitation treatment stage according to the invention is configured to create a mixture of a first fluid and a second fluid and to further generate vapor-filled cavities embedded in the mixture. The first fluid may be a hydrocarbon fuel and the second fluid may be a hydrocarbon fuel of a different type, water, an alcohol, or another liquid. Additionally, the first fluid and/or the second fluid may be inhomogeneous fluids that comprise additives (e.g. an oil, alcohol, or synthetic fuel).

[0012] According to the invention, vapor-filled cavities embedded in the mixture are generated by cavitation. As the person skilled in the art will appreciate, cavitation is the physical process when vapor-filled cavities in a liquid are generated when the static pressure of a liquid is reduced below the liquid's vapor pressure. In other words, at the location where the static pressure of the liquid is reduced below the liquid's vapor pressure, at least a portion of the molecules of the liquid will transition from the liquid phase into the gaseous phase, thereby creating a vapor-filled cavity (or bubble). Since these pressure variations are inhomogeneous, the pressure will be reduced below the liquid's vapor pressure only in small regions within the liquid, the vapor-filled cavities are embedded in the liquid.

[0013] Preferably, the pressure variations in the liquid may be introduced by at least one rotating element. Examples of suitable rotating elements are propeller or geometric elements with holes, recesses, or protrusions. Such geometric elements include discs, plates, cylinders, spheres, hemispheres, among others and combinations thereof. Also, a combination of rotating elements and static elements- so-called stators - may be used. The direction in which the rotating elements are rotating does not need to be uniform. In some embodiments, the rotating elements may rotate in the same direction, whereas in other embodiments, the rotating elements may rotate in different or opposite directions (so-called contra-rotating elements). In some preferred embodiments, the cavitation treatment stage may comprise at least two contra-rotating elements, whereas in other preferred embodiments, the cavitation treatment stage may comprise a combination of at least rotating element and at least one stator element.

[0014] In case two or more rotating elements are used, the rotating elements may be arranged in a stacked arrangement, meaning that they have a common axis of rotation. However, in other examples, the rotating elements may not have a common axis of rotation but may be arrangement in a parallel arrangement, such that their axes of rotation are parallel to one another. In even other examples, the axes of rotation of the two or more rotating elements may not be arranged in any particular order, but rather are arranged arbitrarily.

[0015] During operation, the cavitation treatment stage receives the first liquid (e.g. hydrocarbon fuel) and the second fluid (e.g. hydrocarbon fuel of a different type, water, an alcohol or another liquid).. The term fluid as used herein shall also cover a fluid and any additive as long as the respective aggregate state is fluid. When the first fluid and the second fluid pass through the cavitation treatment stage, the first fluid and the second fluid are mixed. Preferably, the mixing is performed by one or more rotating elements when the first fluid and the second fluid flow around or through the rotating elements. When the one or more rotating elements rotate, they mix the first fluid and the second fluid and preferably at the same time generate vapor-filled cavities embedded in the mixture by causing cavitation. This way, a mixture of the first fluid (e.g. hydrocarbon fuel) and the second fluid (e.g. hydrocarbon fuel of a different type, water, alcohol, or other liquid) is created, wherein vapor-filled cavities are generated and embedded in the mixture. The vapor-filled cavities include vapor of the fluid, e.g. vapor made of water. In some preferred embodiments, a mixture of hydrocarbon fuel (as the first fluid) and water (as the second fluid) is created, wherein vapor-filled cavities are generated and embedded in the hydrocarbon fuel, thereby creating an emulsified hydrocarbon fuel.

[0016] When two or more rotating elements are used, the first fluid and the second fluid may pass the two or more rotating elements in a sequential order (e.g. as would be the case when the two or more rotating elements are stacked) or a portion of the first fluid and the second fluid may pass a first one of the two or more rotating elements while another portion of the first fluid and the second fluid may pass another one of the two or more rotating elements (e.g. as would be the case when the two or more rotating elements are arranged in parallel). In the latter case, the two or more rotating elements may be arranged in a large space through which the first fluid and second fluid will flow or may be arranged in two or more flow passages.

[0017] The one or more resonance frequency treatment stages of the system for treating fluids is configured to increase the amount of gaseous content in the vapor-filled cavities by resonance being introduced into the mixture.

[0018] As mentioned in the context of the one or more cavitation treatment stages, vapor-filled cavities are generated in the mixture of the first fluid and the second fluid. In the one or more resonance frequency treatment stages, the gaseous content within the vapor-filled cavities is increased by applying a resonance frequency. In some applications, the resonance frequency, resonates with the energy of the bonds of the fluid molecules (e.g. the hydrogen-oxygen bond of a water molecule), whereas in other applications the resonance frequency refers to the inherent frequency of the device that forms the resonance frequency treatment stage, meaning that the device acts as resonator. In some preferred embodiments, the geometry or arrangement of the resonance frequency treatment stage and thereby the resonance frequency of the resonance frequency treatment stage may be related to the resonance frequency of the hydrogen-oxygen bond of a water molecule.

[0019] When the resonance frequency treatment stage is operating, resonance frequency is introduced into the mixture of the first fluid and the second fluid, in particular to the vapor-filled cavities, and introduces energy. The energy causes the vapor/liquid molecules within the vapor-filled cavities to dissolve and transition into gaseous form. For example, when water is used as the second fluid, the resonance frequency causes the H_2O molecules to dissolve into hydrogen molecules (H_2) and oxygen molecules (O_2).

[0020] Hence, according to the invention, a first fluid (preferably a hydrocarbon fuel) is mixed with a second fluid (e.g. hydrocarbon fuel of a different type, water, alcohol, or other liquid), vapor-filled cavities are generated in the mixture and the gaseous content in the vapor-filled cavities is increased. In other words, in some preferred embodiments, a hydrocarbon fuel is treated such that it comprises embedded cavities of gaseous content, preferably hydrogen and oxygen for creating an emulsified fuel. When such a treated mixture of hydrocarbon fuel is fed to an internal combustion engine, the combustion is improved because the gaseous content (e.g. gaseous hydrogen and gaseous oxygen) enhances the combustion process.

[0021] In the following, preferred embodiments of the system for treating fluids are described.

[0022] In one embodiment of the system according to the invention, a cavitation treatment stage and a resonance frequency treatment stage may be connected in sequence in a way that the first fluid and the second fluid are received at the cavitation treatment stage, are treated by mixing and generating vapor-filled cavities embedded in the mixture, and the treated mixture is provided to the resonance frequency treatment stage. Afterwards, the resonance frequency treated mixture with increased gaseous content in the vapor-filled cavities can be provided to an engine.

[0023] However, in other embodiments, at least two cavitation treatment stages may be connected in series and at least one resonance frequency treatment stage may be located intermediate relative to the at least two cavitation treatment stages, which are connected in series. This arrangement provides a two-stage cavitation treatment with a resonance frequency treatment located in between. This may particularly improve the mixing of the hydrocarbon fuel and the fluid and the increased gaseous content in the vapor-filled cavities.

[0024] Additionally or alternatively to any of these embodiments, a tap may be added downstream of the treatment stages, wherein the tap may separate the fluid flow into two lines, wherein a first line is for providing the treated fluid to an engine, while the other line is connected upstream to any of the treatment stages, thereby creating a loop or a recirculation line. This way, a portion of the treated fluid can be provided to the engine while another portion of the treated fluid is separated and looped back to the treatment stages for further treatment, which may even further improve the efficiency of the treatment. Depending on the operation mode of the engine, there may be more or less treated fluid needed for combustion and the loop or recirculation line may temporarily store any excess treated fluid by refeeding.

[0025] In some preferred embodiments, one or more of the resonance frequency treatment stages may comprise an assembly of two or more tubes of non-magnetic material, said two or more tubes having a circular cross-section and different diameters and being arranged concentrically. Thereby, the tubes define a plurality of intermediary spaces, which form flow paths for the mixture of the first fluid and the second fluid. Further, an inner tube and an outer tube of the assembly of two or more tubes may be configured to be connected to an electrical current generator.

[0026] This way, a pulsating electrical current (e.g. a pulsating DC current) can be applied to the tubes, the pulsating electrical current creating the resonance.

[0027] In some preferred embodiments, a means for generating an electrical current may be included in the system. For example, each of the one or more resonance frequency treatment stages may comprise an electrical current generator being connected to the respective inner tube and the outer tube of the assembly of two or more tubes and being configured for supplying a fluctuating current or the respective discs of the modules. Alternatively, the system may comprise a common electrical current generator being connected to the respective inner tube and the outer tube of the assembly of two or more tubes of each of the two or more resonance frequency treatment stages and being configured for supplying a fluctuating current.

[0028] The fluctuating current may be a pulsed current with two phase shifted waves that are slightly different in frequency so as to cause resonance or may comprise two different phase currents with different modulation and different frequency. The pulsating current may create charges on the tubes in the range from 0.5 V to 100 kV and may have a current strength in the range from 0.01 A to 1 kA. The duty and pause cycle of the current generator may have a ratio ranging from 0.05 % to 99.05 %. The pulsating current may pulsate according to a sinusoidal, triangle, or square shape, among others.

[0029] In another preferred embodiment, one or more of the resonance frequency treatment stages may comprise one or more modules, each module comprising two plates and an insulator that is placed between the plates and configured to isolate the plates from one another. Further, during operation, one of the plates may have positive charge and the other plate may have negative charge. The charge may be created by an electrical current (e.g. a DC current) that is provided by an electrical current generator. Preferably, the electrical current is a pulsating current as mentioned above. Each plate may comprise an opening that enables flow of the mixture through the respective plate.

[0030] Preferably, the plates may be arranged in a way that their openings do not overlap, meaning that the flow of the mixture will pass through a space between the two plates until it reaches the opening in the other plate. Further, when two or more modules are used, the modules may be stacked. Thereby, the modules may be stacked in a way that the openings of adjacent plates of neighboring modules do not overlap, causing the mixture to flow through a space between neighboring modules until it reaches the respective opening in the next module. Further, when two or more modules are stacked, the modules may be stacked in a way that adjacent plates have opposite charge - for example, a first module has a positive charged plate and a negative charged plate as mentioned above. When a second module is placed adjacent to the first module, either the plate of the second module that has the negative charge is placed next to the plate of the first module that has the positive charge, or the plate of the second module that has the positive charge is placed next to the plate of the first module that has the negative charge. This way, when the mixture flows through the plates of a single module and through the space between neighboring modules, the mixture is surrounded by a negative charged plate on the one side and by a positive charged plate on the other side. When modules are stacked, additional insulators may be placed between the stacked modules.

[0031] In some preferred embodiments, at least one of the one or more cavitation treatment stages comprises two plates that are spaced apart from one another, wherein each plate comprises a first plurality of openings for enabling the mixture to flow through the respective plate and a plurality of permanent magnets placed in receptions within the respective plate. Further, the at least one of the one or more cavitation treatment stages may comprise a rotating disc located between the two plates, wherein the rotating discs comprises a second plurality of openings for enabling flow of the mixture through the rotating disc. Further, at least one of the one or more resonance frequency treatment stages may comprise two stator discs placed between the two plates of the at least one of the cavitation treatment stages and on either side of the rotating disc of said cavitation treatment stage, wherein each stator disc may comprise a third plurality of openings for enabling flow of the mixture through the stator discs. The stator discs may be configured to be connected to an electric current generator, which is configured to generate a fluctuating current, as described above. Thereby, a fluctuating positive charge may be created on one of the two stator discs and a fluctuating negative charge is created on the other stator disc.

[0032] This way, the rotating disc of the at least one cavitation treatment stage causes the mixing of first flued (e.g. hydrocarbon fuel) and the second fluid (e.g. hydrocarbon fuel of another type, water, alcohol, or other liquid) as well as the generation of vapor-filled cavities within the mixture. This is further enhanced by the two plates spaced apart, which comprise the first plurality of openings and the magnets, wherein the magnets enhance the orientation of the molecules within the vapor-filled cavities. The two stator discs of the at least one resonance frequency treatment stage are charged during operation and provide the resonance frequency treatment. Because of the magnets influencing the orientation of the molecules, the molecules are more easily dissolved by the resonance frequency treatment stage. Additionally, third plurality of openings enhances the cavitation processes.

[0033] For this embodiment, it may be said that the resonance frequency treatment stage and the cavitation treatment stage are interleaved, thereby combining the mixing of the first fluid and the second fluid and generating of the vapor-filled simultaneously with the increasing of the gaseous content in the vapor-filled cavities. By combining both processes, they are also enhanced, because the components influence each other and provide additional openings for enhancing the cavitation process and also providing enhanced resonance treatment by using magnetic fields.

[0034] The person skilled in the art will appreciate that one or more of such systems comprising the two plates, the rotating disc and the two stator plates may also be stacked or connected in a loop. In case of a loop, a tap may be located downstream of one of these systems and may separate two lines, one line for providing treated fluid to an engine and one line for looping a portion of the treated fluid back to the one or more systems. In some embodiments of a stack of such systems, the stacked systems may share common plates in order to reduce the overall complexity of the stacked systems. Further, in some embodiments only two plates having the first plurality of openings and the receptions filled with permanent magnets may be present and a plurality of stator discs (three or more) with at least one rotating element placed between two adjacent stator discs may be provided.

[0035] The person skilled in the art will appreciate that the abovementioned preferred embodiments are not exclusive. Instead, the embodiments may be combined. For example in case that multiple resonance frequency treatment stages are used by the system, each resonance frequency treatment stage may have any of the abovementioned configurations. Similarly in case that multiple cavitation treatment stages are used by the system, each cavitation treatment stage may have any of the abovementioned configurations.

[0036] The abovementioned need is also overcome by a system for providing treated fluid to an engine apparatus according to the invention. According to the invention, said system for providing treated fluid to an engine apparatus comprises a preparation line for a first fluid (e.g. hydrocarbon fuel), a preparation line for a second fluid (e.g. a hydrocarbon fuel of a different type, water, alcohol, or other liquid), and a system for treating fluid according to the description above. The system for treating fluid is located downstream of the preparation line for the first fluid and the preparation line for the second fluid. Further, at least one of the preparation line for the first fluid and the preparation line for the second fluid comprises at least one first Halbach array.

[0037] As the person skilled in the art will appreciate, an Halbach array comprises a specific arrangement of permanent magnets, which causes increased magnetic flux on one side of the arrangement, along with highly decreased magnetic flux on the opposite side of the arrangement.

[0038] According to the invention, the Halbach array preferably comprises a cylindrical body. Within the cylindrical body, a stack of rings is placed, wherein each ring comprises magnets that are arranged in an annular fashion along the ring. Preferably, neighboring magnets have opposite orientations, meaning that a first magnet has a north pole facing radially towards the center of the ring and a south pole facing radially outwards of the ring and a neighboring second magnet has a south pole facing radially towards the center of the ring and a north pole facing radially outwards of the rings and so on. Due to this arrangement, the magnetic flux inside the ring is increased. Alternatively, the opposite orientations of neighboring magnets may be achieved by a first magnet having a north pole facing in a downstream flow direction with respect to the flow of the fluid through the Halbach array and a south pole facing in an upstream flow direction and a neighboring second magnet having a south pole facing in a downstream flow direction and a north pole facing in an upstream flow direction and so on.

[0039] Further, the Halbach array comprises a helical shaped structure that is placed within the stack of rings. The helical shaped structure is preferably made of magnetic material, e.g. stainless steel. The helical shaped structure is configured to rotate within the stacked rings.

[0040] During operation of the Halbach array, a flowing medium (e.g. hydrocarbon fuel, fluid (e.g. water), or a mixture of both) will be advanced by a rotating movement of helical shaped structure. Because of the increased magnetic flux within the stacked rings, the flowing medium experiences the influence of the magnetic field lines. When the Halbach array is provided in the preparation line for one of the fluids, it influences the fluid in a way that the fluid molecules (in particular in case of water molecules) will get softer when they stream through the magnetic field on the side of the increased magnetic flux. In case that hydrocarbon fuel flows through the Halbach array, the Halbach array influences the hydrocarbon fuel in a way that certain chemical bonds of the hydrocarbon chains are weakened, which causes the hydrocarbon chains to dissolve into smaller sections of hydrocarbon chains. As the person skilled in the art will appreciate, burning of smaller hydrocarbon chains will result in reduced amount of exhaust gases, which is why the Halbach array can contribute to the reduction of carbon gas emissions from internal combustion engines.

[0041] In another preferred embodiment, the system for providing treated hydrocarbon fuel to an engine apparatus may comprise a second Halbach array located downstream of the system for treating fluids. The second Halbach array may have essentially the same structure and may function as the first Halbach array described above.

[0042] Even more preferred, a first Halbach array may be provided in each of the preparation line for the first fluid and the fluid preparation line for the second fluid and a second Halbach array may be provided downstream of the system for treating fluids.

[0043] Further, the system for providing treated fluids to an engine apparatus may comprise a control unit. The control unit may be configured to determine the temperature and/or pressure at various locations within the system, e.g. the preparation line for the first fluid, the preparation line for the second fluid, any of the Halbach arrays (if any), any location within the system for treating fluids, or a location downstream of the system for treating fluids. The control unit may be configured to control valves that are located throughout the system for providing treated fluids to an engine apparatus and may be configured to control pumps that establish and maintain flow of the first fluid and the second fluid through the system.

[0044] Preferably, the control unit may be configured to operate valves and pumps in a way to keep a ratio of the first fluid and the second fluid constant. Generally, the ratio may be include any range from 5 % to 95 % of the first fluid (e.g. hydrocarbon fuel) combined with the corresponding percentage of second fluid (e.g. water, H_2O), including the particular ratios of (i) 10 % : 90 %, (ii) 20 % : 80 %, (iii) 25 % : 75 %, (iv) 30 % : 70 %, or (v) 50 % : 50 % (in any of these ratios, the first fluid may correspond to the first position of the ratio or the second position). In a preferred example, a ratio of H_2O : fuel = 20 % : 80 % may be provided. As mentioned above, the first fluid and/or the second fluid may be inhomogeneous fluids that comprise additives (e.g. an oil, alcohol, or synthetic fuel). For example (i), this means that in the first fluid : second fluid = 80 % : 20 %, the ratio may comprise 80 % of a first fluid, e.g. hydrocarbon fuel and an additive, and 20 % of a second fluid, e.g. water and an additive.

[0045] Even though the control unit may be formed by multiple control units, a single control unit for synchronized control of the pumps and valves is preferred.

[0046] The abovementioned need can also be addressed by a method according to the invention. The method may be performed by any of the systems for treating fluid disclosed above. The method comprises creating a mixture of a first fluid and a second fluid and generating vapor-filled cavities embedded in the mixture, as well as increasing the amount of gaseous content in the vapor-filled cavities by resonance being introduced into the mixture. The method may use the means of the system for treating fluids as described above. Thereby, in a preferred embodiment, the creating of the mixture and the generating the vapor-filled cavities may be performed by one or more rotating elements.

[0047] Further, the increasing the amount of gaseous content in the vapor-filled cavities may comprise guiding the mixture through an assembly of two or more tubes of non-magnetic material, said two or more tubes having a circular cross-section and different diameters and being arranged concentrically thereby defining a plurality of intermediary spaces, which form flow paths for the mixture, and applying a fluctuating current to an inner tube and an outer tube of the assembly of two or more tubes.

[0048] Alternative, the increasing the amount of gaseous content in the vapor-filled cavities may additionally or alternative comprise guiding the mixture through one or more modules, each module comprising two plates and an insulator that is placed between the plates and configured to isolate the plate from one another, wherein one plate has positive charge and the other plate has negative charge, and wherein each plate comprises a hole that enables flow of the mixture through the respective plate.

[0049] The following description and the annexed drawings set forth in detail certain illustrative aspects of the systems described above. These aspects are indicative, however, of but a few of the various ways in which the principles of various embodiments can be employed and the described embodiments are intended to include all such aspects and their equivalent.

[0050] In the drawings, like reference characters generally refer to the same parts throughout the different drawings. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention.

[0051] In the following description, various embodiments of the invention are described with reference to the following drawings, in which:

FIG. 1 shows a system for treating fluids according to the invention;

FIG. 2 shows a rotating element configured to be employed in a cavitation treatment stage according to the invention;

FIG. 3 shows the elements of a resonance frequency treatment stage according to the invention;

FIG. 4 shows a flow diagram for a method for treating fluids according to the invention;

FIG. 5 shows systems for treating fluids according to two embodiments of the invention;

FIG. 6 shows a system for treating fluids according to another embodiment of the invention;

FIG. 7 shows another system for treating fluids according to the invention, which is based on the principles of the system according to Figure 6;

FIG. 8 shows a system for treating fluids according to the invention, wherein the system comprises one or more Halbach arrays.

[0052] The following detailed description refers to the accompanying drawings that show, by way of illustration, specific details and embodiments in which the invention may be practiced.

[0053] The word "exemplary" is used herein to mean "serving as an example, instance, or illustration". Any embodiment or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments or designs.

[0054] Figure 1 shows a system for treating fluids according to the invention. The system 100 comprises a first fluid supply 108, a second fluid supply 110, a pump 106, a fuel processor 104, and a connection to an engine 102.

[0055] The first and second fluid supplies 108, 110 are connected downstream to the pump 106. The pump 106 is configured to receive the first fluid from the first fluid supply 108 and the second fluid from the second fluid supply 110 and to provide the first fluid and the second fluid to the fuel processor 104. Even though a single pump 106 is depicted in Figure 1, the person skilled in the art will appreciate that each of the first fluid supply 108 and the second fluid supply 110 may be connected to the fuel processor 104 by an individual pump. As mentioned at the beginning of the application, the first fluid may be a hydrocarbon fuel and the second fluid may be a hydrocarbon fuel of a different type, water, an alcohol, or another liquid. Additionally, the first fluid and/or the second fluid may be inhomogeneous fluids that comprise additives (e.g. an oil, alcohol, or synthetic fuel).

[0056] The fuel processor 104 is configured to treat the fluids. The fuel processor may generally comprise one or more cavitation treatment stages and one or more resonance frequency treatment stages. Each of the one or more cavitation treatment stages may be configured to create a mixture of the first fluid and the second fluid and to generate vapor-filled cavities embedded in the mixture. Further, each of the one or more resonance frequency treatment stages may generally be configured to increase the amount of gaseous content in the vapor-filled cavities by resonance being introduced into the mixture.

[0057] The system 100 depicted in Figure 1 may represent a general design of a system for treating fluids according to the invention. Preferred embodiments and implementations will be described in more detail with respect to the following figures.

[0058] Figure 2 shows a rotating element configured to be employed in a cavitation treatment stage according to the invention. The cavitation treatment stages according to the invention may be configured to create a mixture of the first fluid and the second fluid and to generate vapor-filled cavities embedded in the mixture. The cavitation treatment stages may mix the fluids and generate vapor-filled cavities by using one or more rotating elements, which cause cavitation - i.e. the physical process when vapor-filled cavities in a liquid are generated when the static pressure of a liquid is reduced below the liquid's vapor pressure.

[0059] Figure 2 shows one embodiment of a rotating element 200 according to the current invention. However, the person skilled in the art will appreciate that other rotating elements, including known means like propeller, may also be encompassed by the disclosure of the current invention.

[0060] The rotating element 200 generally has a disk-shaped body and a plurality of openings 210. The first and second fluids may stream through the openings 210.

[0061] When the rotating element 200 rotates, the openings 210 cause pressure variations and lead to cavitation.

[0062] In addition to the plurality of openings 210, the rotating element may also comprise another plurality of openings or recesses 220. These other plurality of openings or recesses 220 may be filled with permanent magnets 250. The magnets may enhance the orientation of the molecules within the vapor-filled cavities. Because of the magnets influencing the orientation of the molecules, the molecules may be more easily dissolved by the resonance frequency treatment stage, which is located downstream of the cavitation treatment stage.

[0063] Figure 3 shows the elements of a resonance frequency treatment stage according to the invention. A resonance frequency treatment stage according to one embodiment of the invention may comprise a stack of plates 300a, 300b, wherein each plate comprises an opening 304 and wherein multiple plates are separated from one another by insulators. The openings 304 of the stack of plates may form one or more flow paths between the plates 300a, 300b. Further, the plates 300a, 300b are configured to be charged when a pulsating electrical current is applied to the plates 300a, 300b. In this way, adjacent plates 300a, 300b may be charged with opposite charges. The pulsating current pulsates in order to introduce resonance to the molecules of the vapor-filled cavities of the mixture of fluids in order to dissolve the molecules and break the chemical bonds of the liquid portions of the vapor, thereby increasing the gaseous content within the vapor-filled cavities embedded in the mixture of the first and second fluid.

[0064] As can be seen in Figures 3 (a), (b), each plate 300a, 300b may comprise a plurality of assembly holes that may be used to connect the multiple plates 300a, 300b via bars 306, thereby forming a stack of plates as is illustrated in the explosion drawing in Figure 3 (b). The stack of plates 300a, 300b may additionally comprise one or more cover plates 308 at the top and/or bottom of the stack and may be arranged in a housing (not shown).

[0065] Figure 4 shows a flow diagram for a method for treating fluids according to the invention. The method 400 may be performed by any of the systems for treating fluid disclosed herein. The method 400 comprises creating 402 a mixture of a first fluid and a second fluid and generating 404 vapor-filled cavities embedded in the mixture, as well as increasing 406 the amount of gaseous content in the vapor-filled cavities by resonance being introduced into the mixture.

[0066] In some embodiments, creating 402 the mixture and generating 404 the vapor-filled cavities may be performed by one or more rotating elements as disclosed herein.

[0067] In some embodiments, increasing 406 the amount of gaseous content in the vapor-filled cavities may comprise guiding the mixture through an assembly of two or more tubes of non-magnetic material, said two or more tubes having a circular cross-section and different diameters and being arranged concentrically thereby defining a plurality of intermediary spaces, which form flow paths for the mixture, and applying a fluctuating current to an inner tube and an outer tube of the assembly of two or more tubes. Alternative, increasing 406 the amount of gaseous content in the vapor-filled cavities may additionally or alternative comprise guiding the mixture through one or more modules, each module comprising two plates and an insulator that is placed between the plates and configured to isolate the plate from one another, wherein one plate has positive charge and the other plate has negative charge, and wherein each plate comprises a hole that enables flow of the mixture through the respective plate.

[0068] Figure 5 shows systems for treating fluids according to two embodiments of the invention. Both embodiments are based on the general system 100 illustrated in Figure 1 and comprise a first fluid supply 508, a second fluid supply 510, a pump 506, a fuel processor 504a, 504b, and a connection to an engine 502. Additionally, a loop or recirculation line 505 is shows in a dashed line. Such a loop or recirculation line 505 may be added to the system 500 and may improve the efficiency of the treatment or may provide a temporal storage of treated fluid. The flow of the treated fluid through the loop or recirculation line 505 may be controlled via a valve (not shown), which may be controlled by a controller (not shown). The control may be based on a current or expected need of fluid (e.g. hydrocarbon fuel) in the engine.

[0069] In a first embodiment shown in Figure 5 (a), the fuel processor 504a comprises two cavitation treatment stages 514, 516 connected in series and a resonance frequency treatment stage 512a located between the two cavitation treatment stages 514, 516.

[0070] The cavitation treatment stages 514, 516 may comprise one or more rotating elements. For example, the cavitation treatment stages 514, 516 may comprise one or more rotating discs 200 as illustrated in Figure 2. In a particularly preferred embodiment example, the cavitation treatment stages 514, 516 may each comprise a stack of rotating discs 200. The discs 200 of the stack of rotating discs may rotate in the same direction or may be contra-rotating discs. Additionally, the rotating discs may rotate with different rotation frequencies. Using variations of the rotation direction and the frequency of the rotation of adjacent discs in the stack of rotating discs may improve the cavitation process and may enhance the mixing by increasing the turbulence of the flow of the fluids within the cavitation treatment stages 514, 516.

[0071] The resonance frequency treatment stage 512a may comprise an assembly of two or more tubes of non-magnetic material, said two or more tubes having a circular cross-section and different diameters and being arranged concentrically. Thereby, the tubes define a plurality of intermediary spaces, which form flow paths for the mixture of the first fluid and the second fluid. Further, an inner tube and an outer tube of the assembly of two or more tubes may be configured to be connected to an electrical current generator. This way, a pulsating electrical current (e.g. a pulsating DC current) can be applied to the tubes, the pulsating electrical current creating the resonance.

[0072] The system 500b illustrated in Figure 5 (b) may be similar to the system 500a of Figure 5 (a), with the exception of the resonance frequency treatment stage 512b of the fuel processor 504b.

[0073] The resonance frequency treatment stage 512b may comprise a plurality of stacked plates that comprise openings for forming a flow path through the plurality of stacked plates, wherein the plates are configured to be charged by an applied pulsating electrical current (e.g. a DC current), as was for example described with respect to Figure 3.

[0074] Figure 6 shows a system for treating fluids according to another embodiment of the invention. The system 600 that is illustrated in the block diagram of Figure 6 (a) is based on the general system 100 illustrated in Figure 1 and comprises a first fluid supply 608, a second fluid supply 609, a pump 606, a fuel processor 604, and a connection to an engine 602. Additionally, a loop or recirculation line 605 is shows in a dashed line, similarly to the loop or recirculation line 505 of the systems 500a, 500b depicted in Figures 5 (a), (b).

[0075] The fuel processor 604 of system 600 combines the cavitation treatment stage and the resonance frequency treatment stage, as is illustrated in Figure 6 (b).

[0076] The fuel processor 604 of Figure 6 (b) comprises two plates 610a, 610b that are spaced apart from one another, wherein each plate 610a, 610b comprises a first plurality of openings 655 (see Figure 6 (d)) for enabling the mixture to flow through the respective plate 610a, 610b and a plurality of permanent magnets 660 (see Figures 6 (b), (c)) placed in receptions 650 (see Figures 6 (b) to (d)) within the respective plate 610a, 610b. Further, the fuel processor 604 comprises a rotating disc 630 located between the two plates 610a, 610b, wherein the rotating disc 630 comprises a second plurality of openings 635 (see Figure 6 (e)) for enabling flow of the mixture through the rotating disc 630. The rotating disc may be connected to a driving shaft 640, which may be connected to a motor (see "M" in Figure 7). Further, the fuel processor 604 comprises two stator discs 620a, 620b placed between the two plates 610a, 610b and being placed on either side of the rotating disc 630. Each stator disc 620a, 620b comprises a third plurality of openings 625 (see. Figure 6 (e)) for enabling flow of the mixture through the stator discs 620a, 620b. The stator discs 620a, 620b may be configured to be connected to an electric current generator, which is configured to generate a fluctuating current, as described above. Thereby, a fluctuating negative charge may be created on one of the two stator discs 620a and a fluctuating positive charge is created on the other stator disc 620b.

[0077] This way, the rotating disc 630 causes the mixing of the first fluid (e.g. hydrocarbon fuel) and the second fluid (e.g. hydrocarbon fuel of another type, water, alcohol, or other liquid) as well as the generation of vapor-filled cavities within the mixture. This is further enhanced by the two plates 610a, 610b spaced apart, which comprise the first plurality of openings 655 and the magnets 660, wherein the magnets 660 enhance the orientation of the molecules within the vapor-filled cavities. The two stator discs 620a, 620b are charged during operation and provide the resonance frequency treatment. Because of the magnets 660 influencing the orientation of the molecules, the molecules are more easily dissolved by the resonance frequency treatment stage. Additionally, third plurality of openings 625 of the stator discs enhances the cavitation processes, because even though the stator discs 620a, 620b are not rotating, the mixed fluid is in motion and will experience additional turbulence by the third plurality of openings 625. As can be seen in Figure 6 (e), the rotating disc 630 may comprise an additional opening in which the driving shaft 640 may be placed - here the driving shaft 640 may be connected to the rotating plate -, while the stator disc 620a also may comprise an additional opening 622 for receiving the driving shaft 640, but here the driving shaft 640 also reaches through the opening 622 without being connected to the stator disc 620a (as mentioned above, the stator discs 620a, 620b do not rotate). The stator disc 620b may have the same or a similar configuration as stator disc 620b depicted in Figure 6 (e).

[0078] For this embodiment, it may be said that the resonance frequency treatment stage and the cavitation treatment stage are interleaved, thereby combining the mixing of the first fluid and the second fluid and generating of the vapor-filled simultaneously with the increasing of the gaseous content in the vapor-filled cavities. By combining both processes, they are also enhanced, because the components influence each other and provide additional openings for enhancing the cavitation process and also providing enhanced resonance treatment by using magnetic fields.

[0079] While Figure 6 (b) shows a cross-sectional view of a fuel processor 604 according to the invention, Figures 6 (c) to (e) show the individual components of the fuel processor 604, wherein (c) and (d) show perspective view, including a cross-section for illustration, and (e) shows top views and additional cross-sectional views as indicated by the dashed lines.

[0080] Figure 7 shows another system for treating fluids according to the invention, which is based on the principles of the system according to Figure 6. Figure 7 shows an embodiment example 700 of a fuel processor which is based on fuel processor 604, but comprises a stack of the components similar to the fuel processor 604 illustrated in Figure 6 (b). Such a stack 700 may improve the efficiency of the fuel processing by performing cavitation and resonance frequency treatment in an interleaved manner repeatedly. The system 700 may comprises and inlet 710 and an outlet 720, which are configured to receive, respectively release the fluids from the system 700. Additionally, a motor M is depicted, which is connected to a driving shaft 640.

[0081] Figure 8 shows a system for treating fluids according to the invention, wherein the system comprises one or more Halbach arrays. The system 800 that is illustrated in the block diagram of Figure 8 (a) is based on the general system 100 illustrated in Figure 1 and comprises a first fluid supply 808, a second fluid supply 810, a pump 806, a fuel processor 804, and a connection to an engine 802. Additionally, a loop or recirculation line 805 is shows in a dashed line, similarly to the loop or recirculation line 505 of the systems 500a, 500b depicted in Figures 5 (a), (b).

[0082] The fuel processor 804 may have any configuration of the systems for treating fluids according to the invention that are described herein, in particular any of the fuel processors described with reference to Figures 1 to 7.

[0083] Moreover, between the pump 806 and the first fluid supply 808, a first Halbach array 850a is located. Also, another first Halbach array 850b is located between the pump 806 and the second fluid supply 810. Even though it is not shown the figure, the person skilled in the art will appreciate that alternatives of the system 800, in which only one of the first Halbach arrays 850a, 850b are present or in which a second Halbach array is placed between the fuel processor 804 and the connection to the engine 802 or within the loop or recirculation line 805, are also encompassed by the current disclosure.

[0084] An Halbach array comprises a specific arrangement of permanent magnets, which causes increased magnetic flux on one side of the arrangement, along with highly decreased magnetic flux on the opposite side of the arrangement. Figure 8 (b) illustrates one specific embodiment example of an Halbach array 850 in an explosion drawing. The Halbach array 850 may be used as first Halbach array 850a, 850b or second Halbach array according to the system 800 illustrated in figure 8 (a).

[0085] The Halbach array 850 comprises a cylindrical body (not shown). Within the cylindrical body, a stack of rings 870 is placed, wherein each ring 870 comprises magnets 890 that are arranged in an annular fashion along the ring. Preferably, neighboring magnets have opposite orientations. Further, the Halbach array 850 comprises a helical shaped structure 880 that is placed within the stack of rings 870. The helical shaped structure 880 is preferably made of magnetic material, e.g. stainless steel. The helical shaped structure 880 is configured to rotate within the stacked rings 870. An inner cylinder 860 may be placed within the stack of rings 870 in order to provide a sealed volume within the stack of rings 870, so that the fluid(s) that are passed through the Halbach array 850 do not leak.

[0086] A rotating movement of helical shaped structure 880 can be used to advance the fluid(s) through the Halbach array 850. Because of the increased magnetic flux within the stacked rings, the fluid(s) experience the influence of the magnetic field lines. When the Halbach array 850 is provided in the preparation line for one of the fluids 808, 810, it influences the fluid in a way that the fluid molecules (in particular in case of water molecules) will get softer when they stream through the magnetic field on the side of the increased magnetic flux. In case that hydrocarbon fuel flows through the Halbach array 850, the Halbach array 850 influences the hydrocarbon fuel in a way that certain chemical bonds of the hydrocarbon chains are weakened, which causes the hydrocarbon chains to dissolve into smaller sections of hydrocarbon chains. As the person skilled in the art will appreciate, burning of smaller hydrocarbon chains will result in reduced amount of exhaust gases, which is why the Halbach array can contribute to the reduction of carbon gas emissions from internal combustion engines.

[0087] Further, the person skilled in the art will appreciate that the Halbach array 850 illustrated in Figure 8 (b) represents only one example of an Halbach array and that other Halbach array configurations may be used without departing from the current invention.

[0088] What has been described above includes examples of one or more embodiments. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the aforementioned embodiments, but one of ordinary skill in the art may recognize that many further combinations and permutations of various embodiments are possible. Accordingly, the described embodiments are intended to embrace all such alterations, modifications and variations that fall within the scope of the appended claims. None of the describes embodiments shall be seen limiting and they may be combined in any way or for that fits the purpose of the invention.

Claims

1. A system for treating fluids, the system comprising:

one or more cavitation treatment stages (514, 516), each of the one or more cavitation treatment stages (514, 516) configured to:

create a mixture of a first fluid and a second fluid, wherein at least one of the first fluid or the second fluid is a hydrocarbon fuel, and generate vapor-filled cavities embedded in the mixture; and

one or more resonance frequency treatment stages (512a, 512b), each of the one or more resonance frequency treatment stages (512a, 512b) configured to:
increase the amount of gaseous content in the vapor-filled cavities by resonance being introduced into the mixture.

2. The system according to claim 1, wherein the one or more cavitation treatment stages (514, 516) comprise at least two cavitation treatment stages (514, 516) connected in series, and
wherein at least one of the one or more resonance frequency treatment stages (512a, 512b) is located intermediate relative to the at least two cavitation treatment stages (514, 516).

3. The system according to any of the preceding claims, wherein at least one of the one or more cavitation treatment stages (514, 516) comprises:
one or more rotating elements (200, 630) configured to mix the first fluid and the second fluid and to generate vapor-filled cavities embedded in the mixture of the first fluid and the second fluid by rotating.

4. The system according to claim 3, wherein the one or more rotating elements (200, 630) comprise at least one of one or more propellers or one or more geometric objects, wherein at least one of the geometric objects comprises a plurality of holes and wherein the one or more geometric objects include one or more discs, one or more plates, one or more cylinders, one or more spheres, one or more hemispheres, or any combination thereof.

5. The system according to any of the preceding claims, wherein at least one of the one or more resonance frequency treatment stages (512a, 512b) comprises:
an assembly of two or more tubes of non-magnetic material, said two or more tubes having a circular cross-section and different diameters and being arranged concentrically thereby defining a plurality of intermediary spaces, which form flow paths for the mixture, wherein an inner tube and an outer tube of the assembly of two or more tubes are configured to be connected to an electrical current generator, which is configured to apply a fluctuating current.

6. The system according to any of the preceding claims, wherein at least one of the one or more resonance frequency treatment stages (512a, 512b) comprises:
one or more modules, each module comprising two plates (300a, 300b) and an insulator that is placed between the plates (300a, 300b) and configured to isolate the plates (300a, 300b) from one another, wherein each plate (300a, 300b) comprises an opening that enables flow of the mixture through the respective plate (300a, 300b).

7. The system according to claim 6, wherein the two plates (300a, 300b) of each module are configured to be connected to an electric current generator, which is configured to generate a fluctuating current, thereby creating a fluctuating positive charge on one of the two plates (300a, 300b) of each module and creating a fluctuating negative charge on the other of the two plates (300a, 300b) of each module.

8. The system according to claim 1 or 2, wherein at least one of the one or more cavitation treatment stages (514, 516) comprises:

two plates (610a, 610b) that are spaced apart from one another, wherein each plate (610a, 610b) comprises a first plurality of openings (655) for enabling the mixture to flow through the respective plate (610a, 610b) and a plurality of permanent magnets (660) placed in receptions (650) within the respective plate (610a, 610b), and
a rotating disc (630) located between the two plates (610a, 610b) wherein the rotating disc (630) comprises a second plurality of openings (635) for enabling flow of the mixture through the rotating disc (630), and
wherein at least one of the one or more resonance frequency treatment stages (512a, 512b) comprises two stator discs (620a, 620b) placed between the two plates (610a, 610b) of the at least one of the cavitation treatment stages (514, 516) and on either side of the rotating disc (630) of said cavitation treatment stage (514, 516), wherein each stator disc (620a, 620b) comprises a third plurality of openings (625) for enabling flow of the mixture through the stator discs (620a, 620b).

9. The system according to claim 8, wherein the two stator discs (620a, 620b) are configured to be connected to an electric current generator, which is configured to generate a fluctuating current, thereby creating a fluctuating positive charge on one of the two stator discs (620a, 620b) and creating a fluctuating negative charge on the other stator disc (620a, 620b).

10. A system for providing treated fluid to an engine apparatus, the system comprising:

a preparation line for a first fluid (108, 508, 608, 708);
a preparation line for a second fluid (110, 510, 609, 710); and
a system (104, 504a, 504b, 604, 804) for treating fluids according to any of claims 1 to 9, wherein the system (104, 504a, 504b, 604, 804) for treating fluids is located downstream of the preparation line for the first fluid (108, 508, 608, 808) and the preparation line for the second fluid (110, 510, 609, 810);
wherein at least one of the preparation line for the first fluid (108, 508, 608, 808) and the preparation line for the second fluid (110, 510, 609, 810) comprises at least one first Halbach array (850, 850a, 850b).

11. The system for providing treated fluid to an engine apparatus according to claim 10, further comprising at least one second Halbach array (850, 850a, 850b) located downstream of the system (104, 504a, 504b, 604, 804) for treating fluids.

12. A method for treating fluids, the method comprising:

creating (402) a mixture of a first fluid and a second fluid, wherein at least one of the first fluid or the second fluid is a hydrocarbon fuel;
generating (404) vapor-filled cavities embedded in the mixture; and
increasing (406) the amount of gaseous content in the vapor-filled cavities by resonance being introduced into the mixture.

13. The method according to claim 12, wherein the creating (402) the mixture of the first fluid and the second fluid and the generating (404) the vapor-filled cavities are performed by one or more rotating elements (200, 630).

14. The method according to claim 12 or 13, wherein the increasing (406) the amount of gaseous content in the vapor-filled cavities comprises:

guiding the mixture of the first fluid and the second fluid through an assembly of two or more tubes of non-magnetic material, said two or more tubes having a circular cross-section and different diameters and being arranged concentrically thereby defining a plurality of intermediary spaces, which form flow paths for the mixture; and
applying a fluctuating current to an inner tube and an outer tube of the assembly of two or more tubes.

15. The method according to claim 12 or 13, wherein the increasing (406) the amount of gaseous content in the vapor-filled cavities comprises:

guiding the mixture of the first fluid and the second fluid through one or more modules, each module comprising two plates (300a, 300b) and an insulator that is placed between the plates (300a, 300b) and configured to isolate the plate (300a, 300b) from one another, wherein each plate (300a, 300b) comprises an opening (304) that enables flow of the mixture through the respective plate (300a, 300b); and
applying a fluctuating current to the two plates (300a, 300b) of each module, thereby creating a fluctuating positive charge on one plate (300a, 300b) of each module and creating a fluctuating negative charge on the other plate (300a, 300b) of each module.

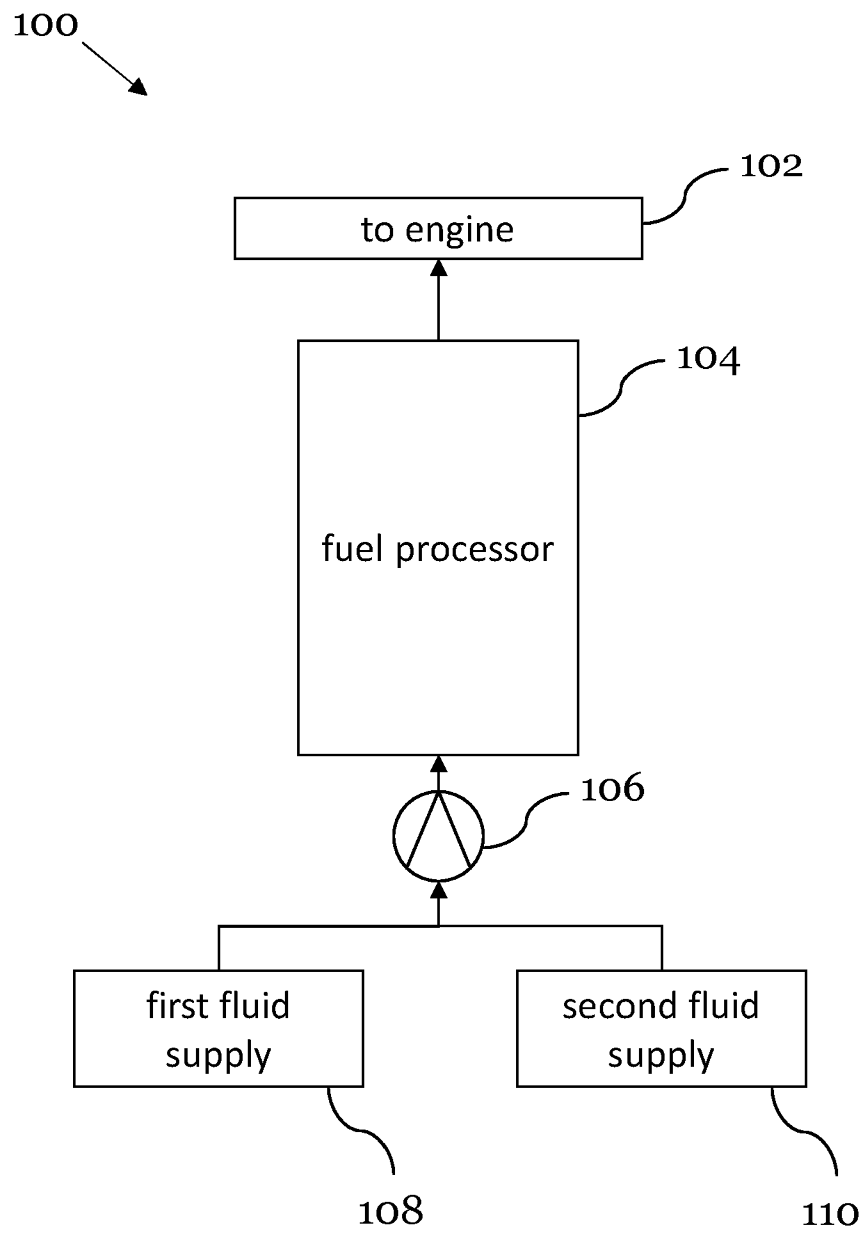

100
102
to engine
104
fuel processor
106
first fluid supply
second fluid supply
108
110

Fig. 1

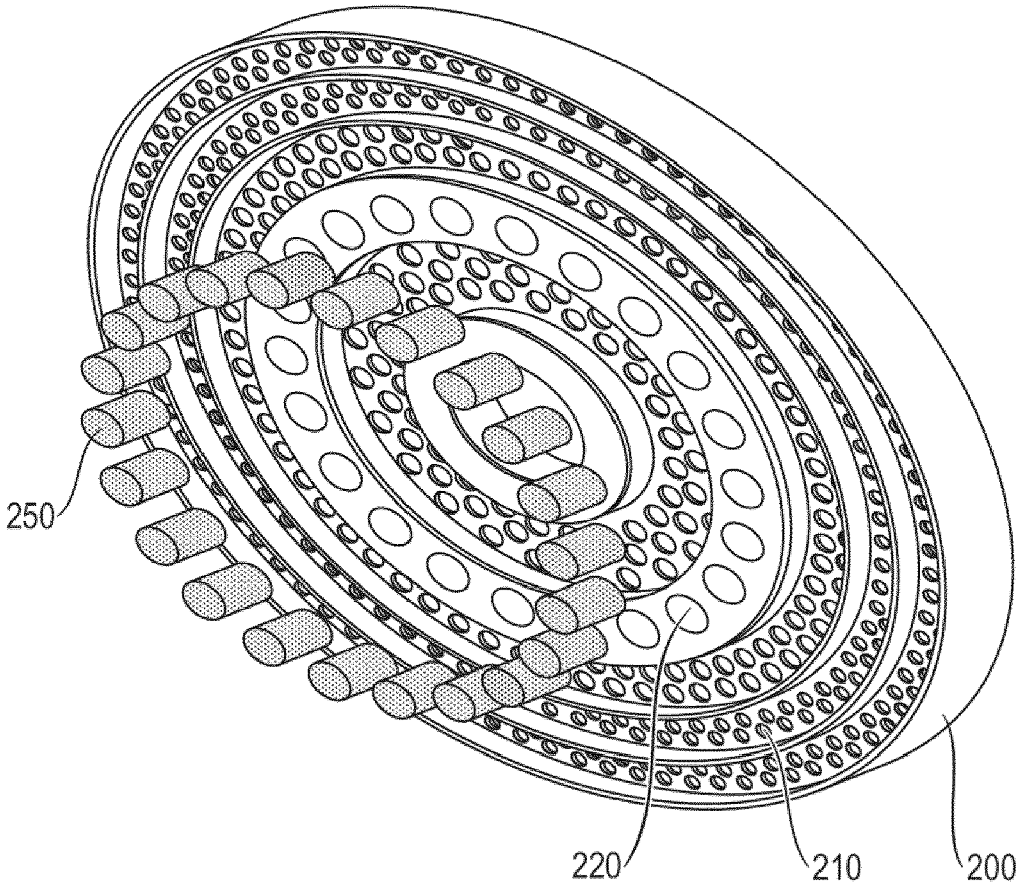


Fig. 2

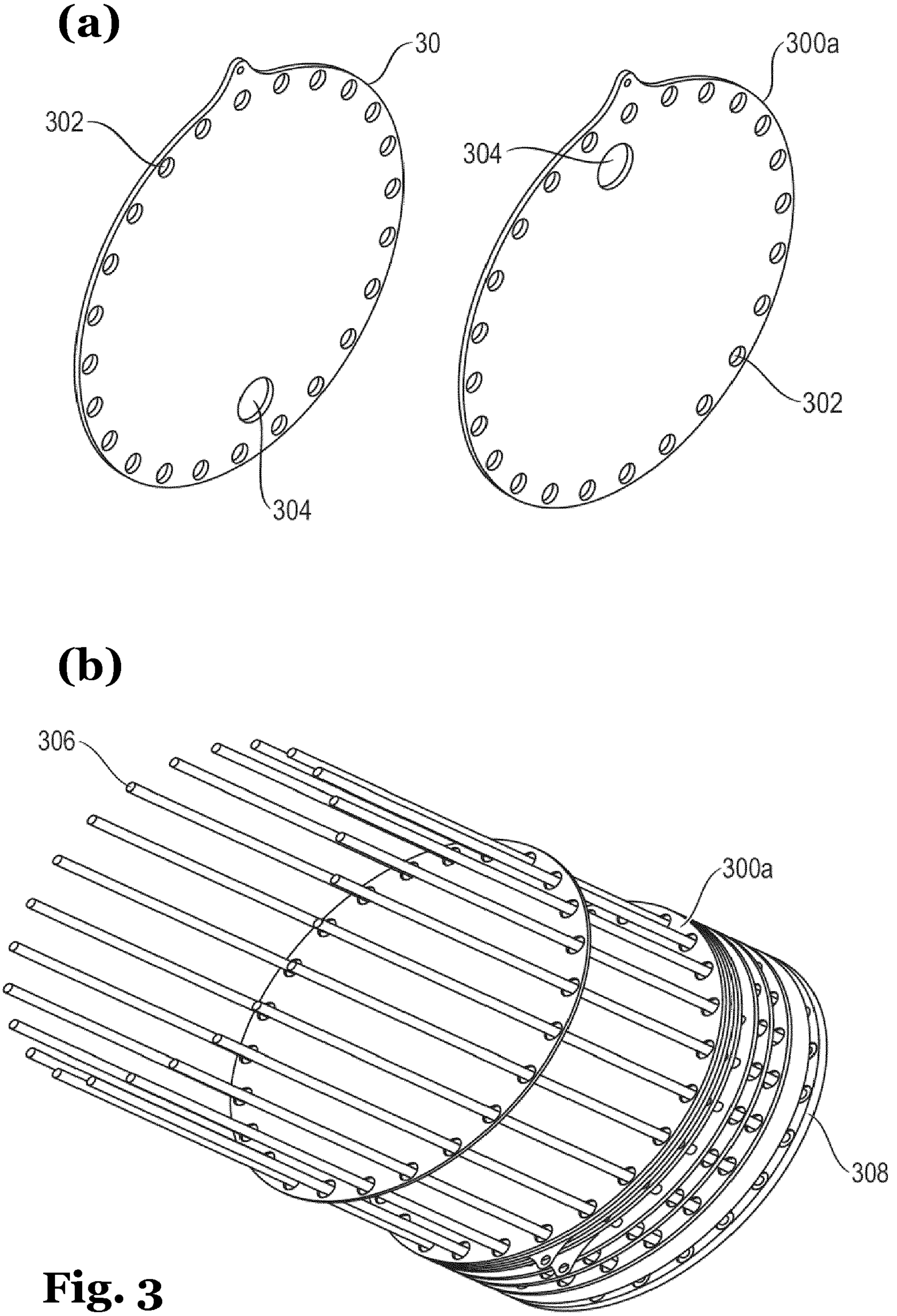


Fig. 3

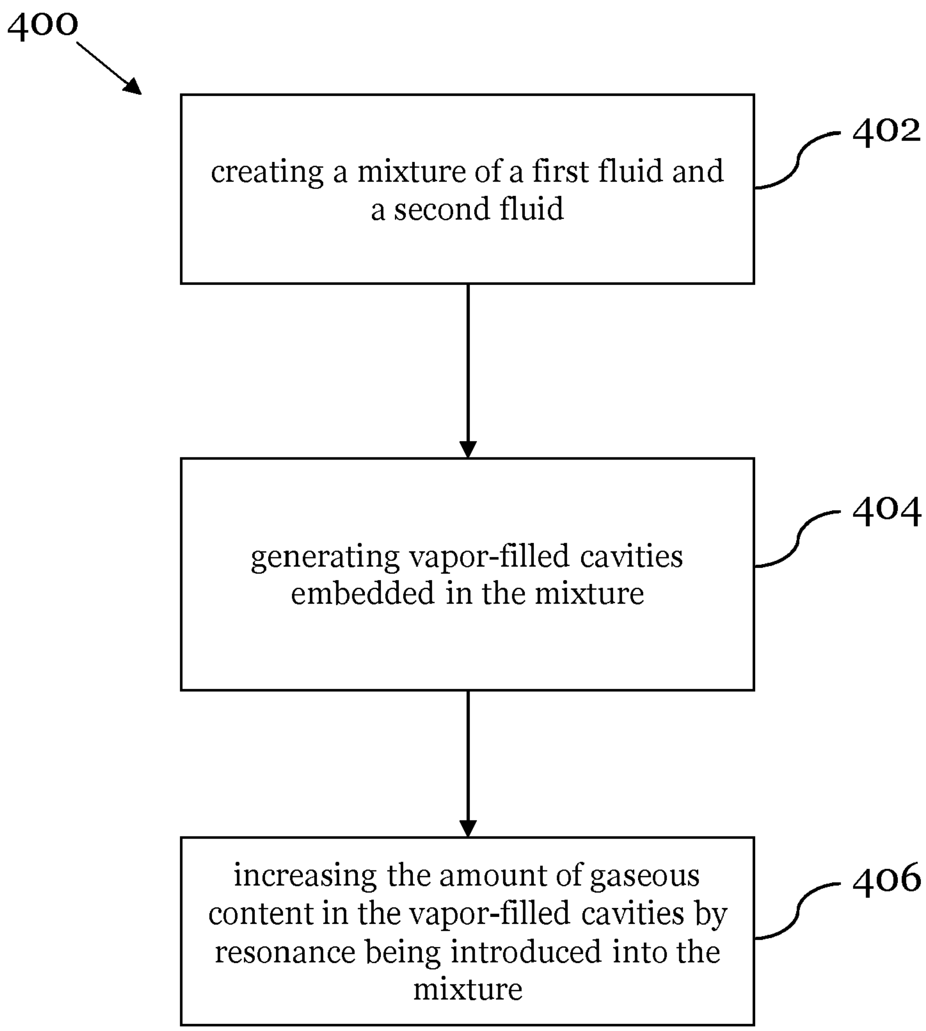

400
creating a mixture of a first fluid and a second fluid
402
generating vapor-filled cavities embedded in the mixture
404
increasing the amount of gaseous content in the vapor-filled cavities by resonance being introduced into the mixture
406

Fig. 4

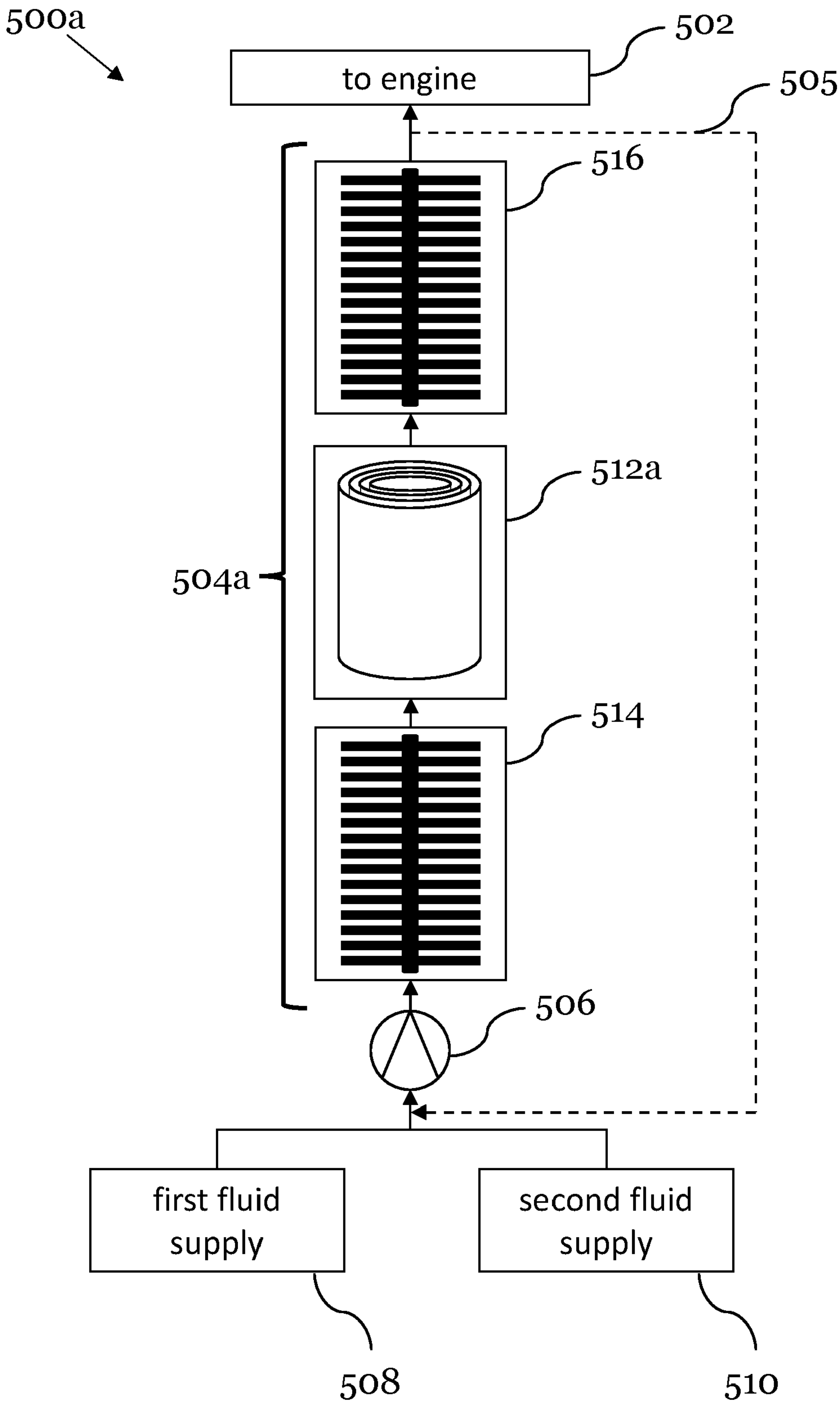

500a
502
to engine
505
516
512a
504a
514
506
first fluid supply
second fluid supply
508
510

Fig. 5a

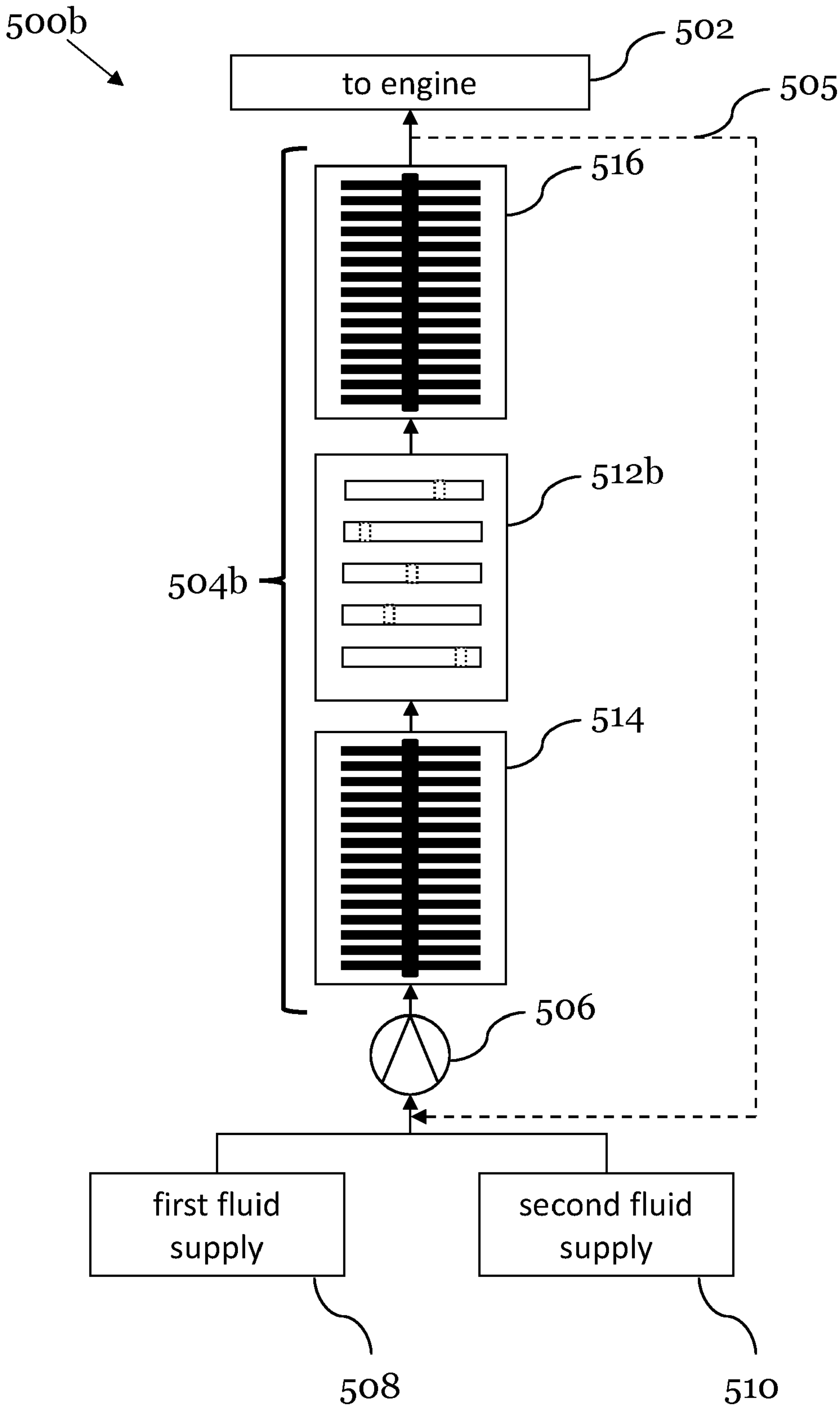
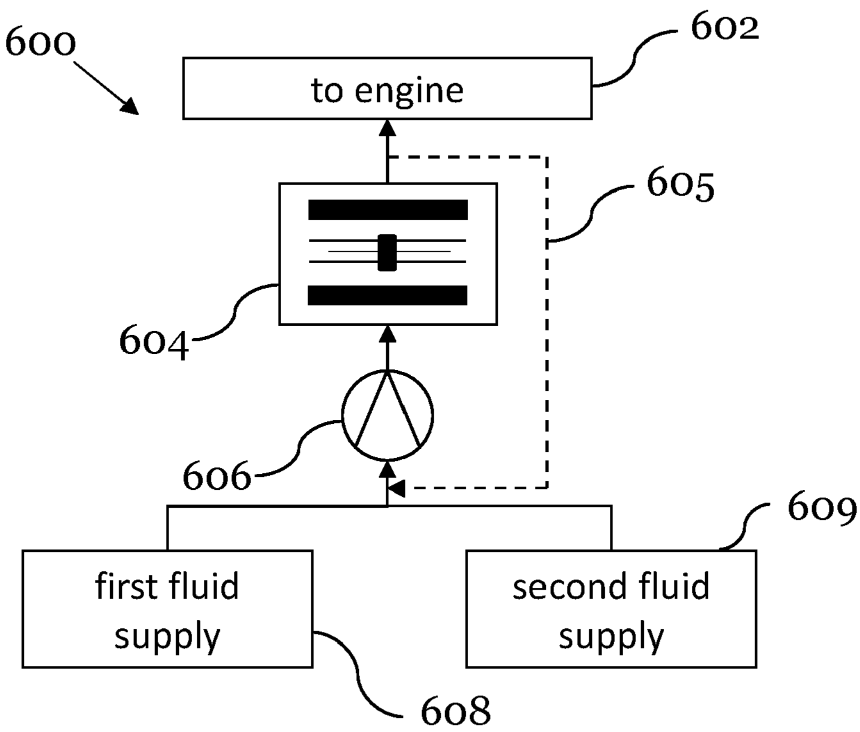

500b
to engine
502
505
516
512b
504b
514
506
first fluid supply
second fluid supply
508
510

Fig. 5b

(a)


600
to engine
602
605
604
606
609
first fluid supply
second fluid supply
608

(b)

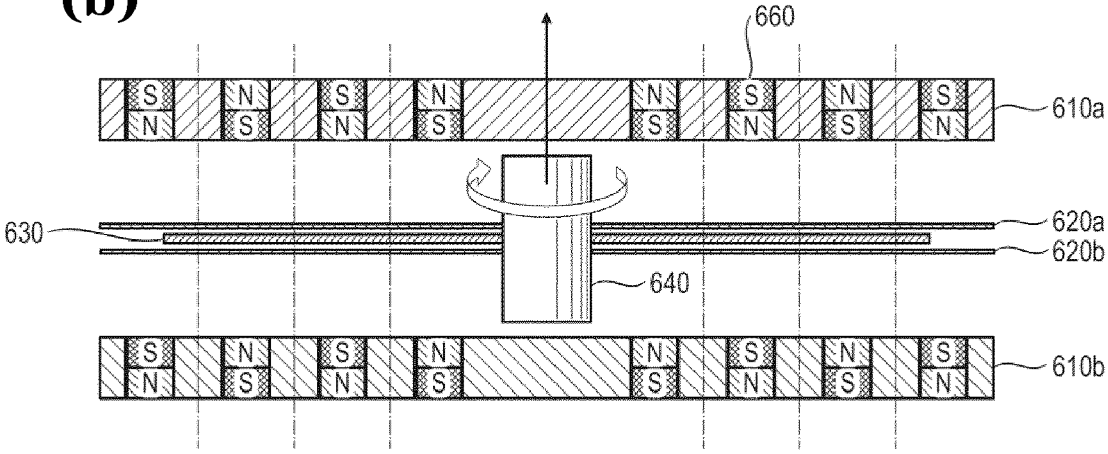
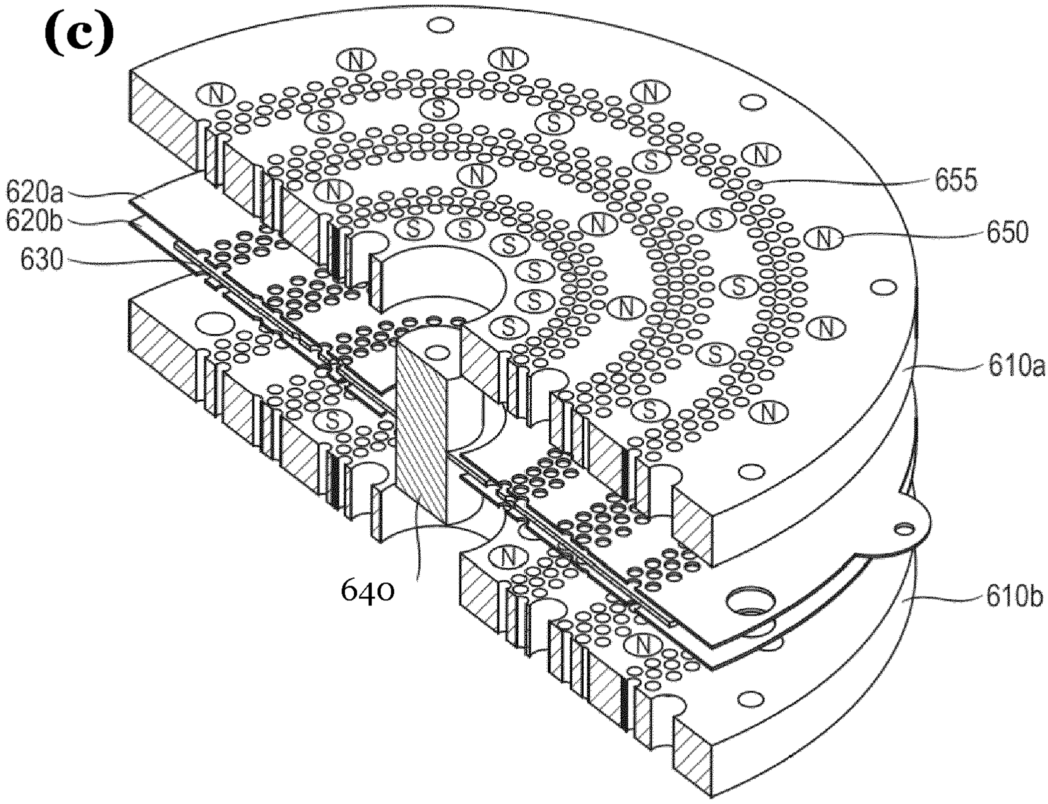

660
610a
630
620a
620b
640
610b

Fig. 6

(c)



(d)

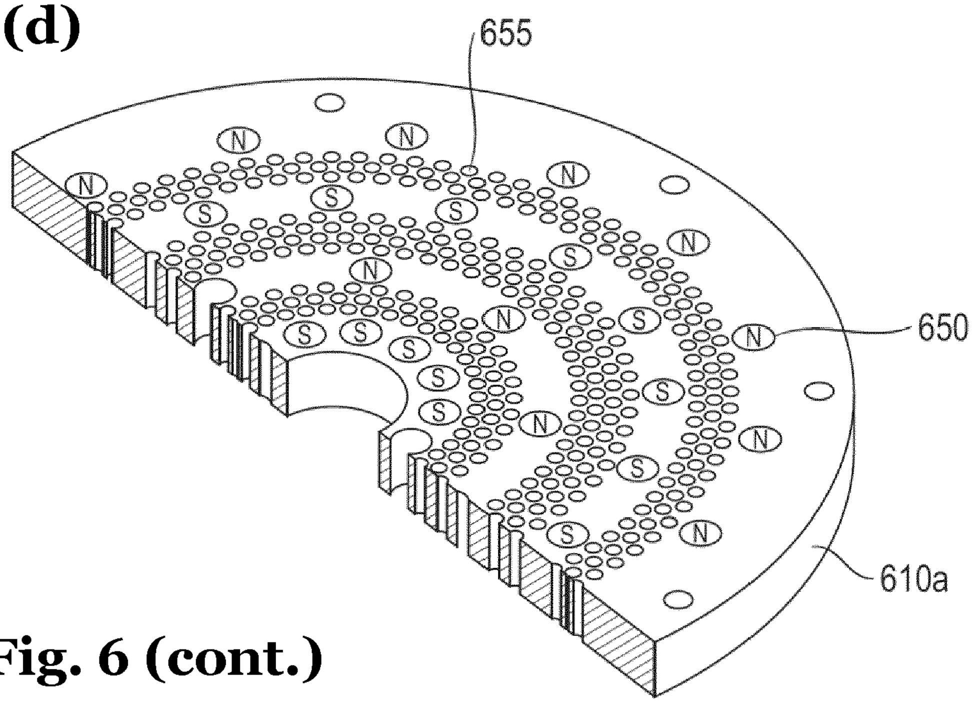


Fig. 6 (cont.)

(e)

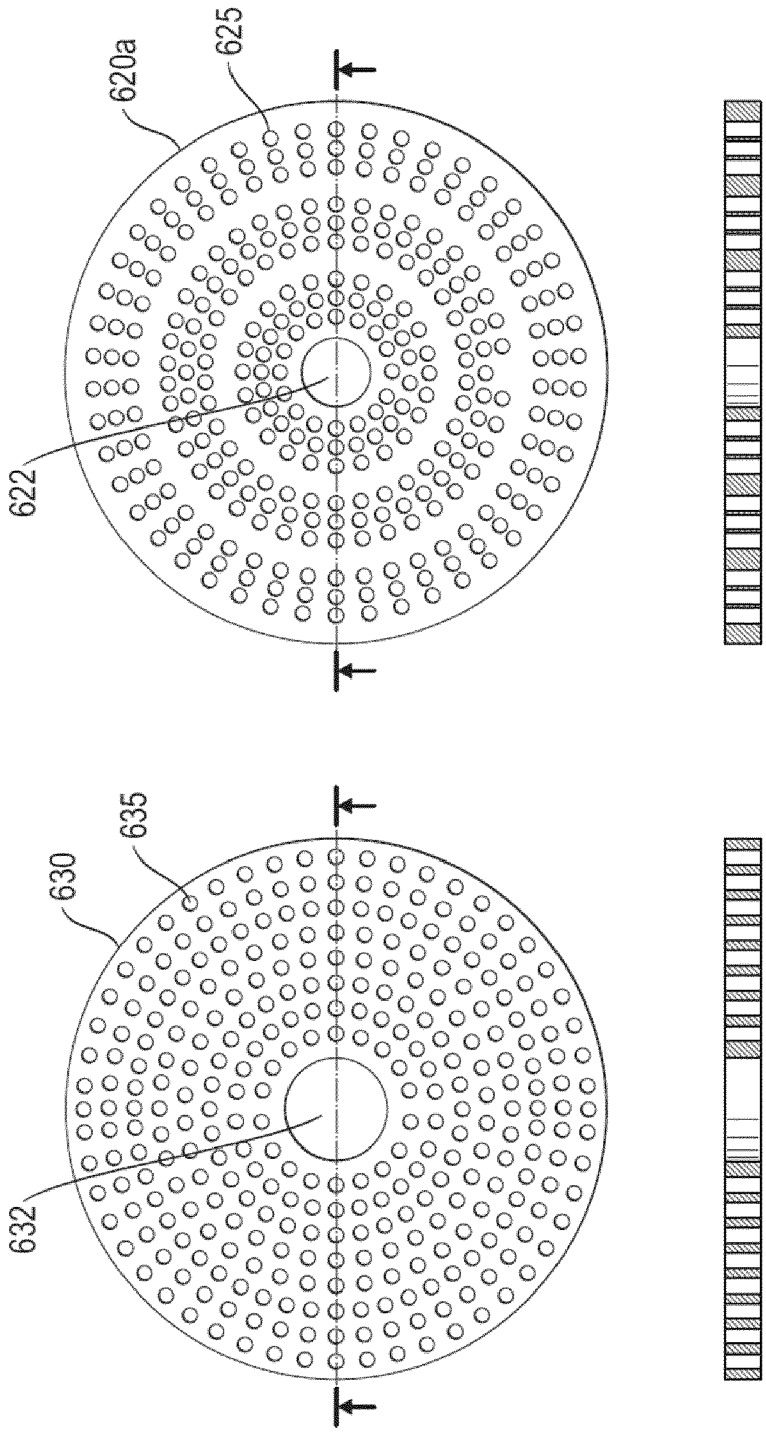


Fig. 6 (cont.)

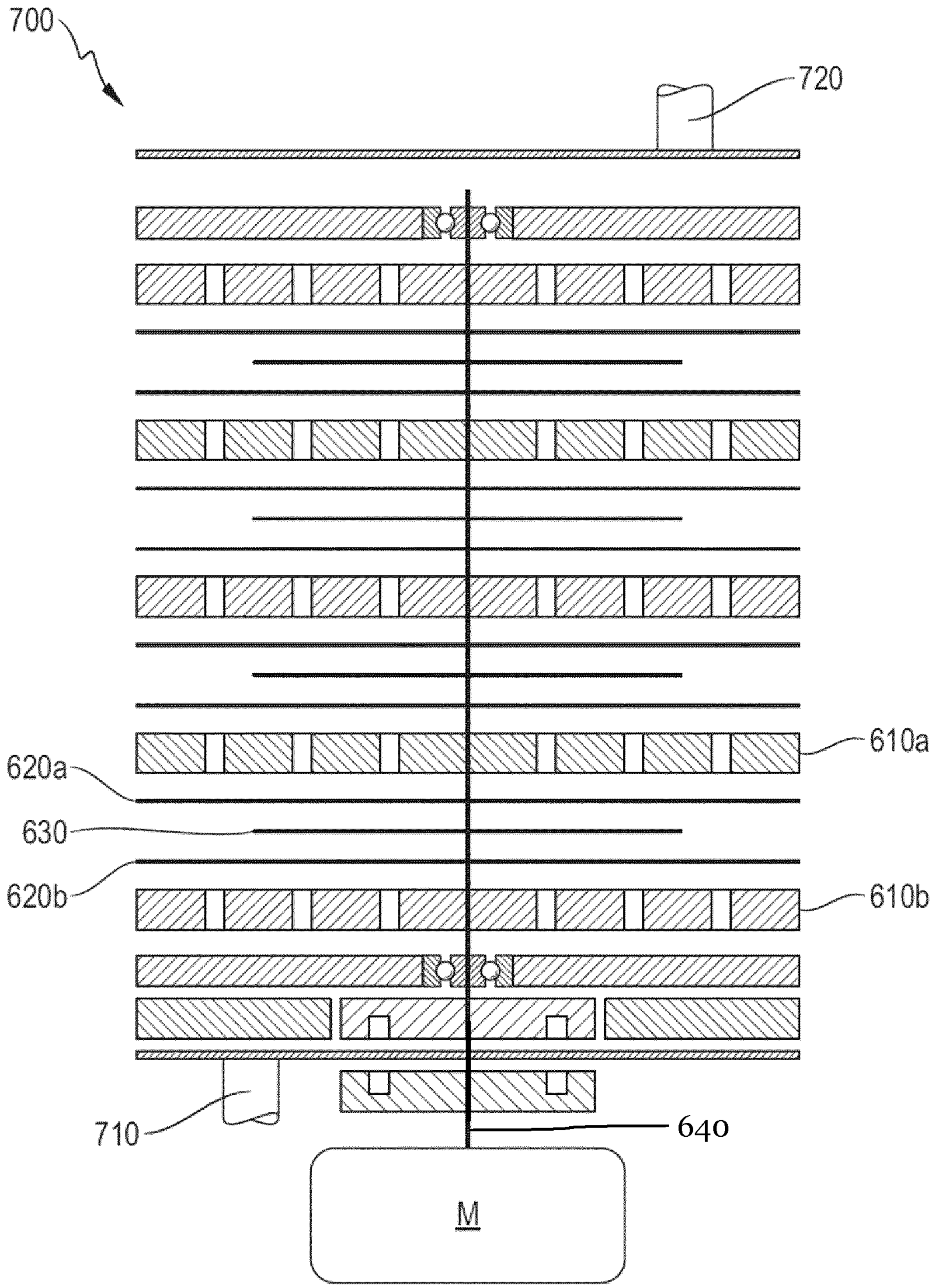


Fig. 7

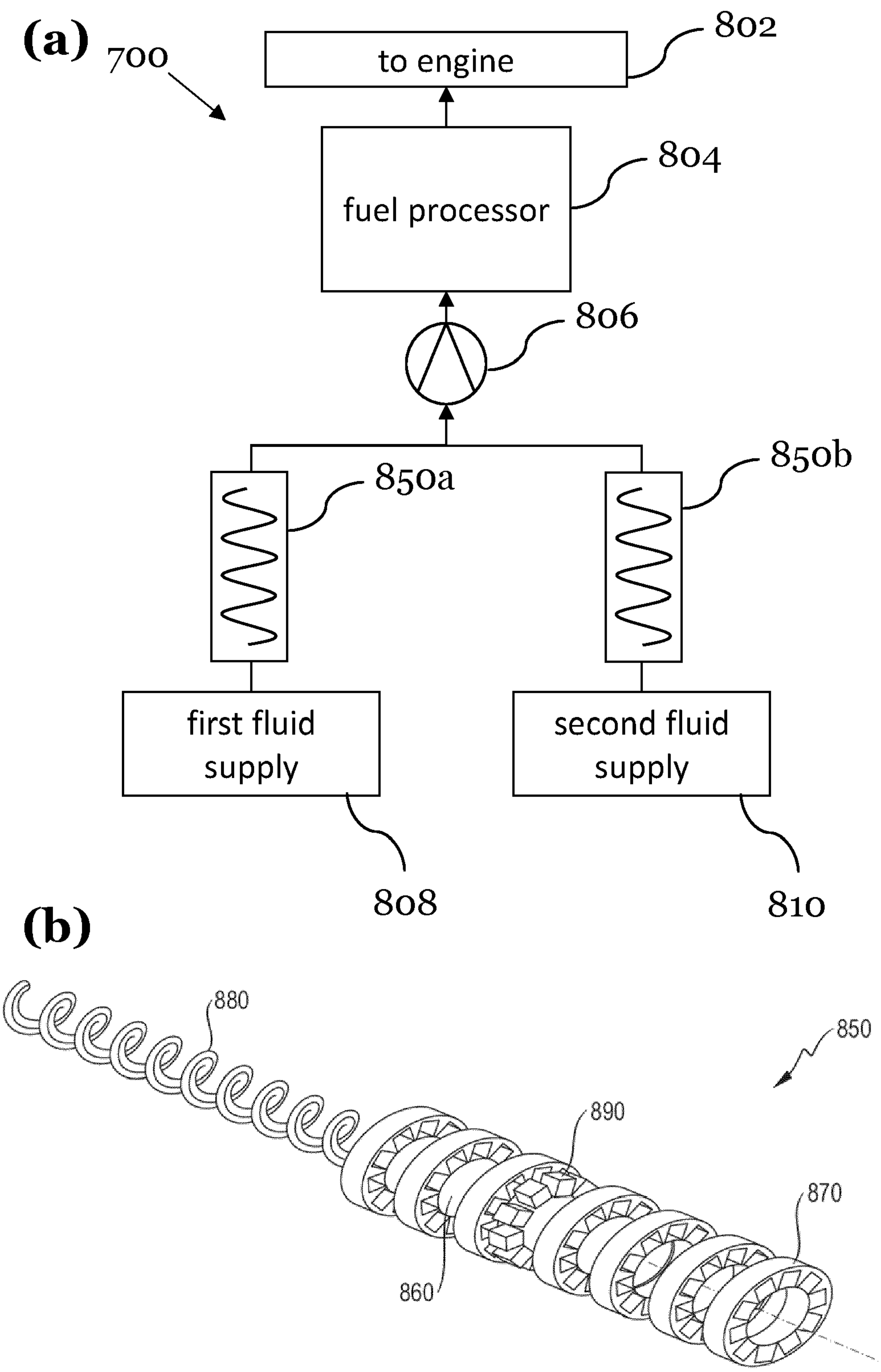

(a)
700
to engine
802
fuel processor
804
806
850a
850b
first fluid supply
second fluid supply
808
810
(b)
880
850
890
870
860

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 23 18 1520

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	9 November 2023	Juvenelle, Cyril

CATEGORY OF CITED DOCUMENTS

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page 1 of 2

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EUROPEAN SEARCH REPORT

Application Number
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TECHNICAL FIELDS SEARCHED (IPC)

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Place of search	Date of completion of the search	Examiner
Munich	9 November 2023	Juvenelle, Cyril

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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P : intermediate document

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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
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EPO FORM 1503 03.82 (P04C01)

page 2 of 2

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The members are as contained in the European Patent Office EDP file on
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09-11-2023

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