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(54) **MAGNETOCALORIC HEAT PUMP, COOLING DEVICE AND METHOD OF OPERATING THEREOF**

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(57) **ABSTRACT**

A magnetocaloric heat pump with a regenerator assembly and a rotatable field generator, containing: a shaft, oriented along a rotation axis and inserted into an axial orifice of a regenerator body of the regenerator assembly and into an axial orifice of a generator body of the rotatable field generator, the rotatable field generator, wherein the generator body is peripherally situated in a periphery of the rotation axis, the generator body containing a first and a second magnetic ring section, which are located diametrically opposite to each other in relation to the rotation axis, wherein the rotatable field generator is attached to the shaft, and the regenerator assembly, wherein the regenerator body is peripherally situated in a periphery of a rotation axis, the regenerator body containing a magnetocaloric material distributed in the regenerator body and wherein the regenerator assembly is arranged around the shaft.

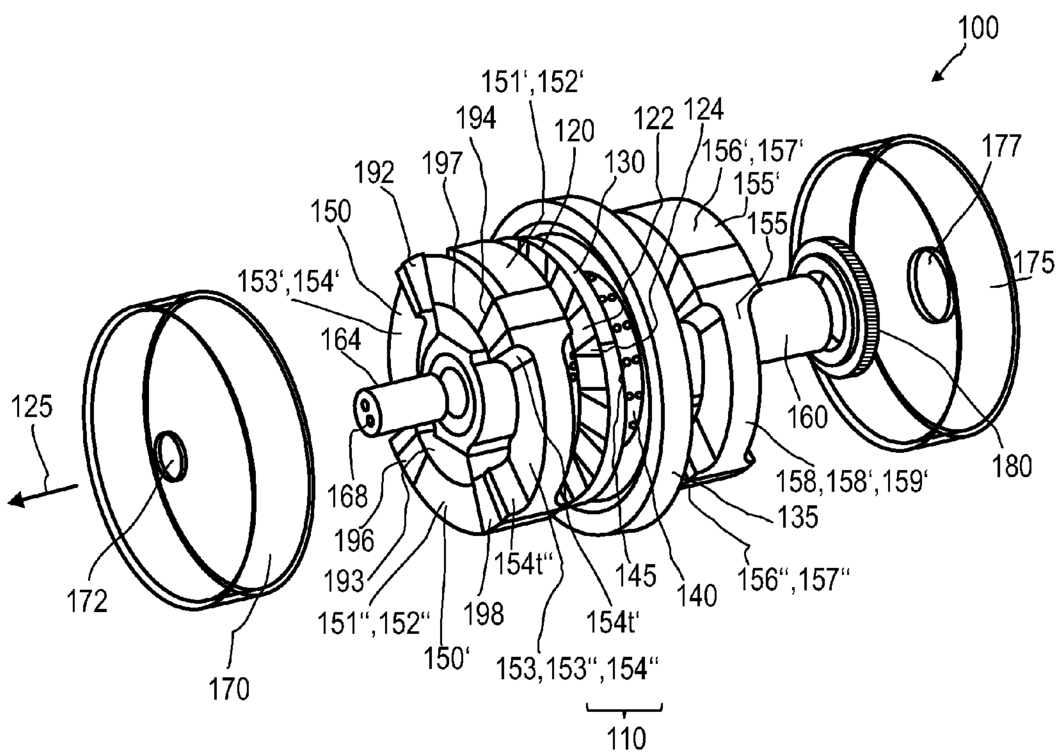
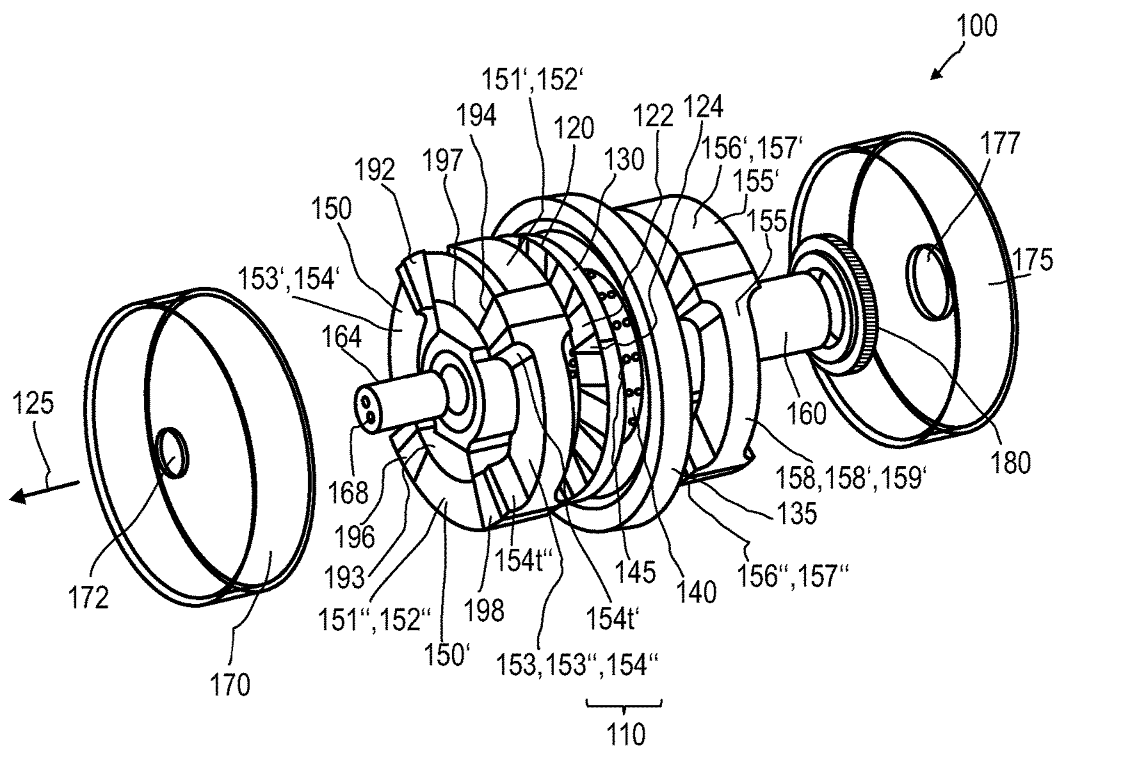


FIG.1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170
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FIG.2

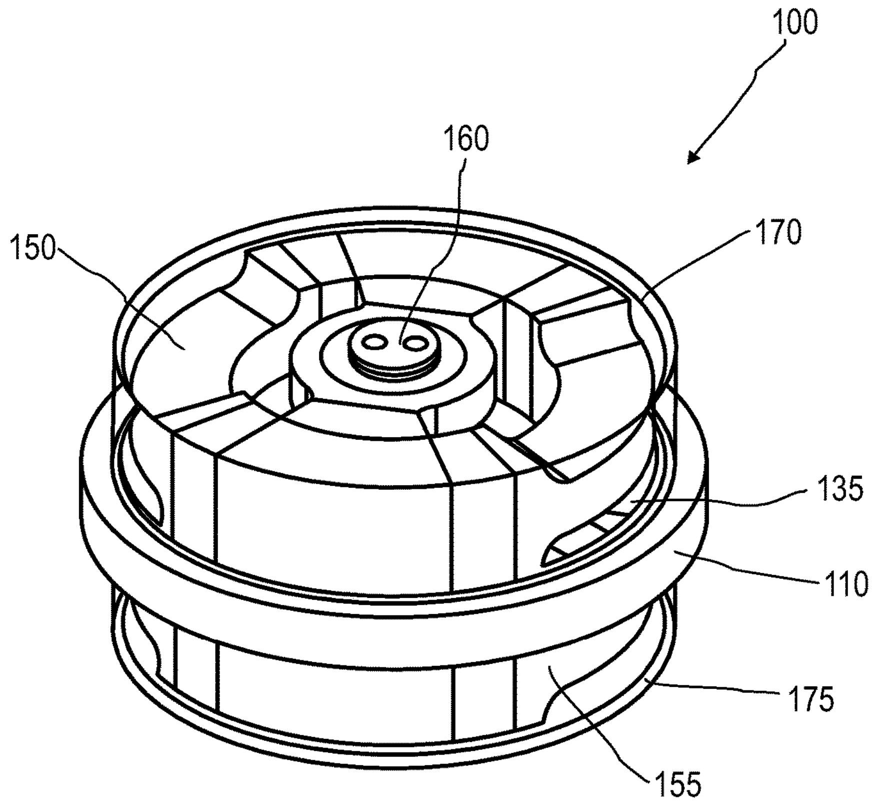

FIG.3

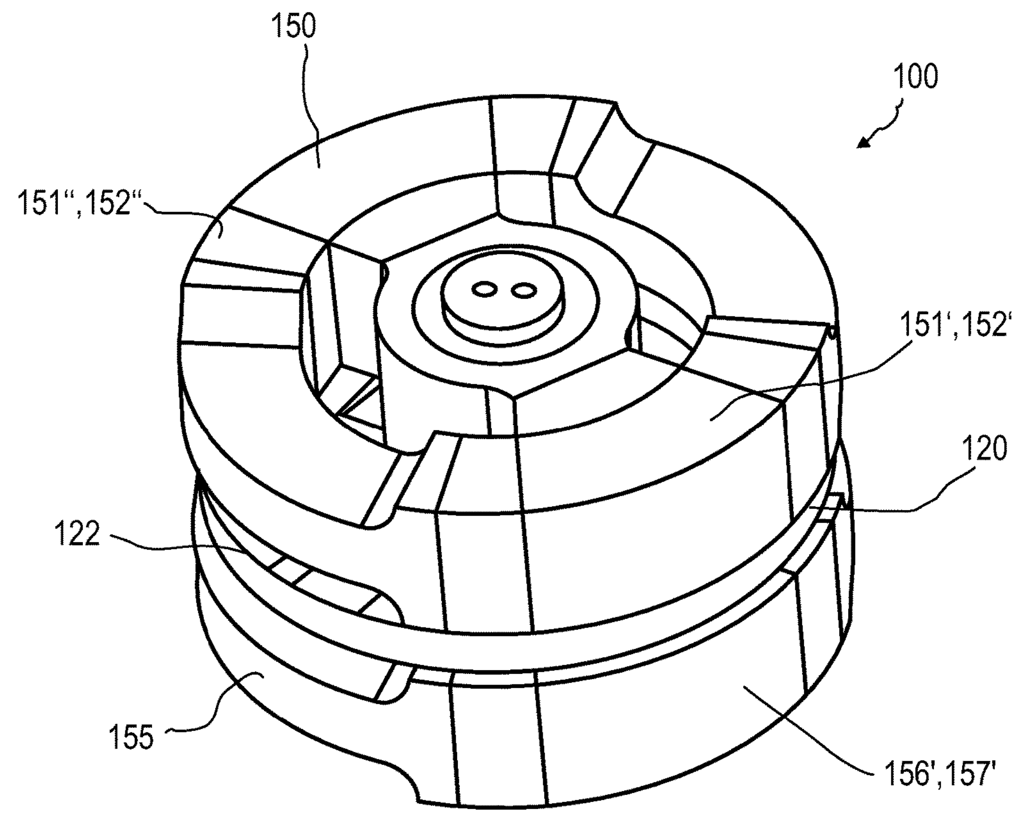

FIG.4

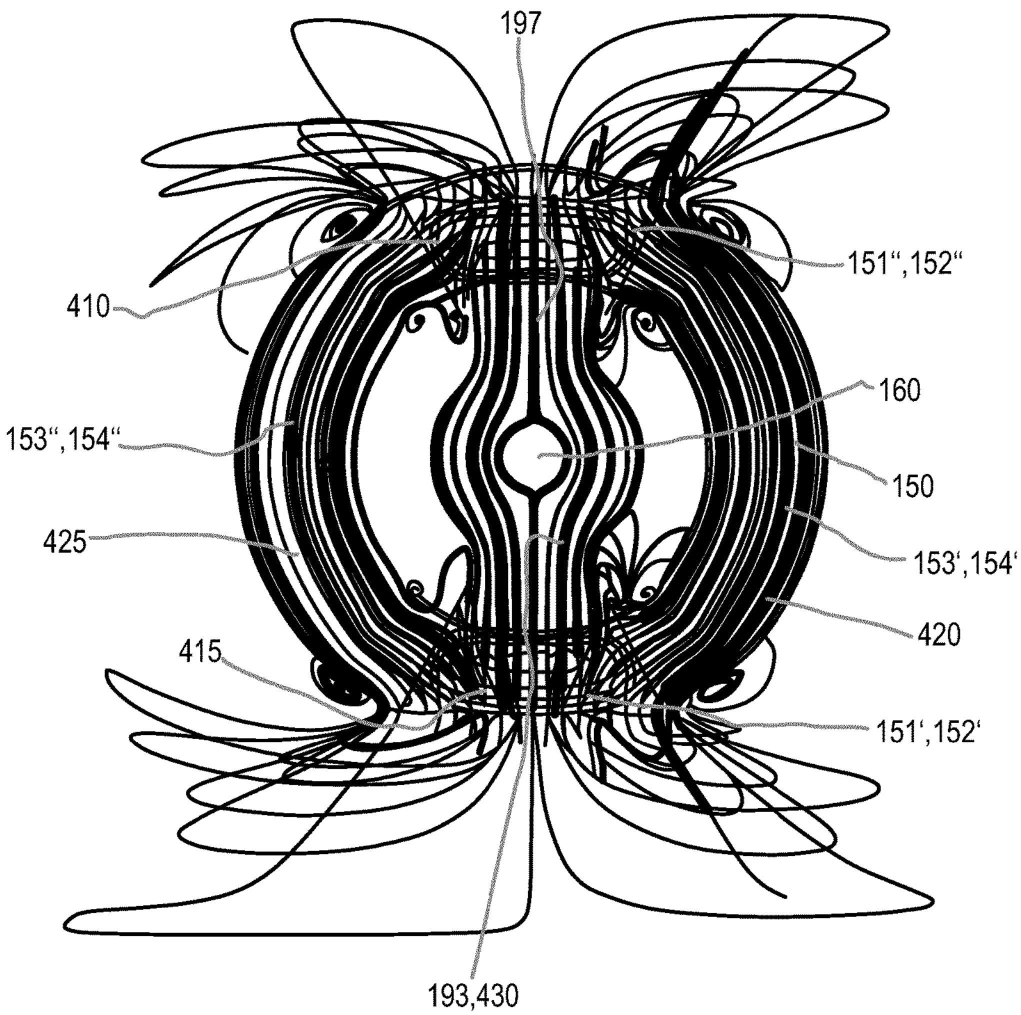
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FIG.5

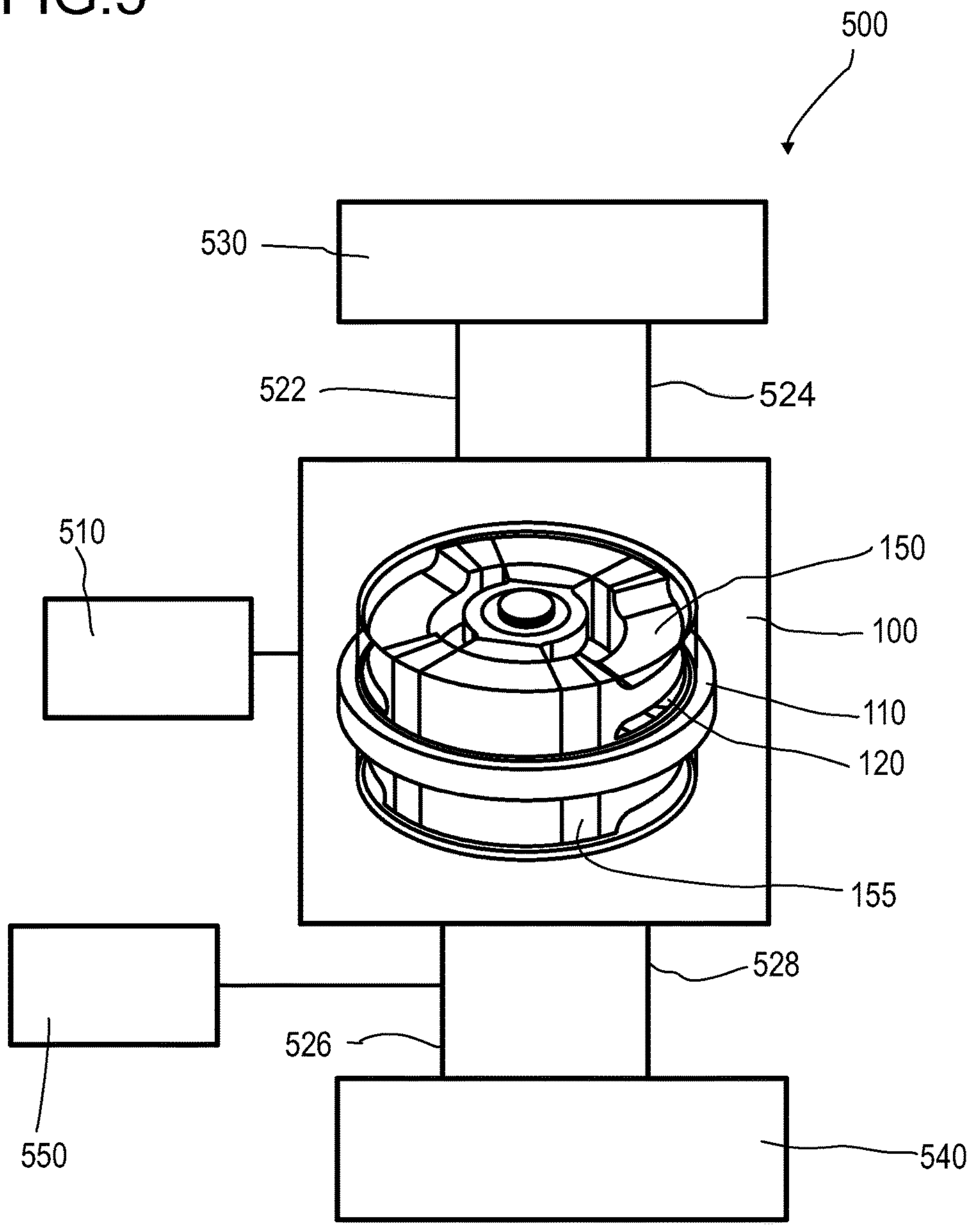


FIG.6

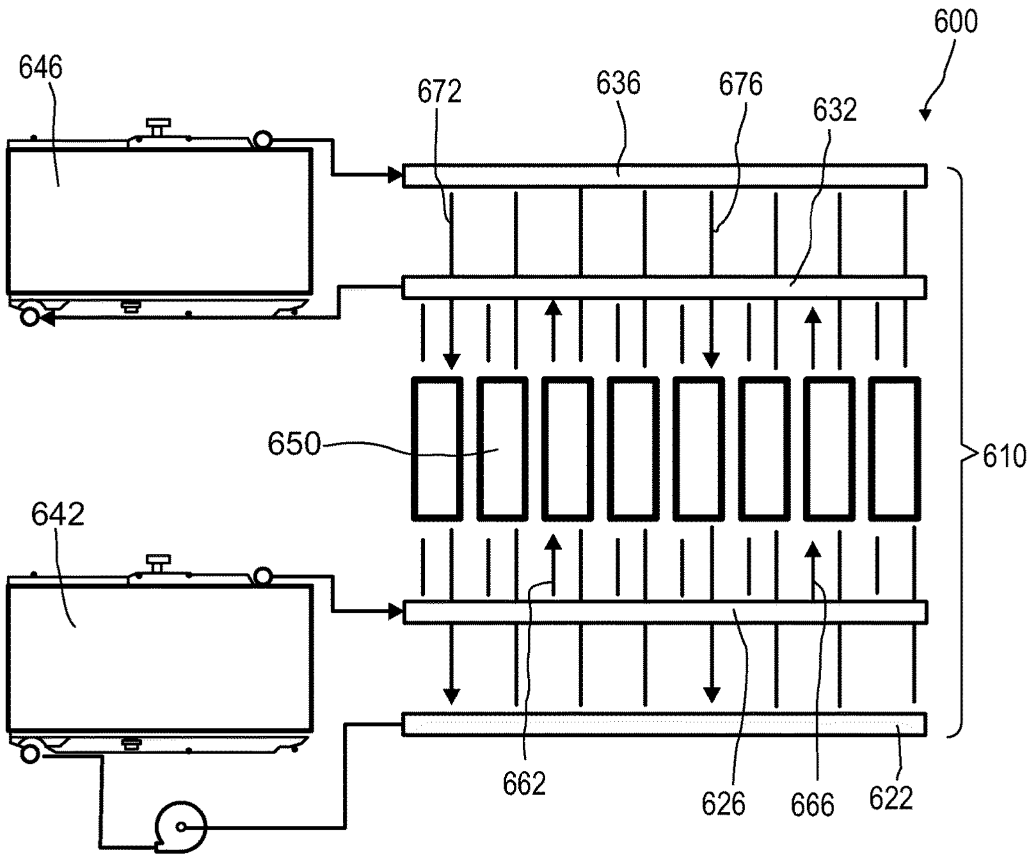
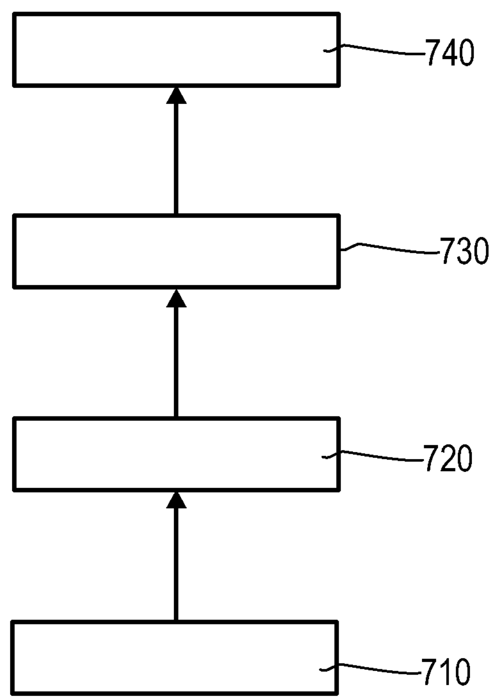


FIG.7



MAGNETOCALORIC HEAT PUMP, COOLING DEVICE AND METHOD OF OPERATING THEREOF

[0001] The invention relates to a magnetocaloric heat pump according to the preamble part of claim **1**, to a cooling device according to the preamble part of claim **14** and further relates to a method for operating a magnetocaloric heat pump according to the preamble part of claim **16**.

[0002] Magnetocaloric materials can be used for pumping heat because they change their temperature upon an application and removal of an external magnetic field.

[0003] The magnetocaloric effect occurs under application of an external magnetic field to a suitable magnetocaloric material and under an ambient temperature in the vicinity of its Curie temperature. The applied external magnetic field causes an alignment of the randomly aligned magnetic moments of the magnetocaloric material from a disordered paramagnetic phase to an ordered ferromagnetic phase and thus a magnetic phase transition, which can also be described as an induced increase of the Curie temperature of the material above the ambient temperature. This magnetic phase transition implies a decrease in magnetic entropy ΔS_{mag} and in an adiabatic process (thermal isolation from the ambient temperature) leads to an increase in the entropy contribution of the crystal lattice of the magnetocaloric material by phonon generation in order to conserve entropy under the adiabatic condition. As a result of applying the external magnetic field, therefore, a temperature rise (ΔT) of the magnetocaloric material occurs.

[0004] In technical cooling applications, this additional heat is removed from the material by heat transfer to an ambient heat sink in the form or a heat transfer medium. Water is an example of a heat transfer medium used for heat removal from the magnetocaloric material.

[0005] Subsequently, removing the external magnetic field can be described as a decrease of the Curie temperature back below an initial temperature of the magnetocaloric material, and thus allows the magnetic moments reverting back to a random arrangement. The external magnetic field is removed under conditions that could be generally considered as adiabatic, but still heat exchange between magnetocaloric material and heat transfer medium occurs, which means that the overall entropy within the system stays nearly unchanged. Since the magnetic entropy increases to its starting level without the external magnetic field, the entropy contribution of the crystal lattice of the magnetocaloric material itself is reduced, and under adiabatic process conditions, thus, results in a cooling of the magnetocaloric material below the ambient temperature. Therefore the temperature of the magnetocaloric material falls below the initial temperature.

[0006] The described process cycle including magnetization and demagnetization is typically performed periodically in device applications.

[0007] Promising "Design improvements of a permanent magnet active magnetic refrigerator" are described in the respective article of D. S. Arnold et al. in the International Journal of Refrigeration Vol. 37 (2014) pg. 99-105. Therein, in an active regenerator, the magnet arrays consist of three concentric cylinders. Each cylinder is constructed using twelve permanent magnet segments. The inner magnet array is stationary while the intermediate and outer arrays are designed to rotate in opposite directions so as to create a sinusoidal magnetic field waveform with a stationary field direction with regard to Halbach arrays of magnetocaloric material.

[0008] US 2014/0165594 A1 describes another device application by discussing a heat pump system having magnetocaloric material positioned in a continuously rotating regenerator. The magnetocaloric material is staged so that, as the regenerator is rotated, a portion of the material is cycled in and out of a magnetic field in a continuous manner. A heat transfer fluid is circulated through the magneto caloric material simultaneously along at least two paths to provide for the transfer of heat both to and from the material in a cyclic manner. The magnetocaloric material may include zones having different temperature ranges of responsiveness to the magnetic field.

[0009] In the article of C. Aprea et al. in the International Journal of Refrigeration Vol. 43 (2014) pg. 111-122 "Initial experimental results from a rotary permanent magnet magnetic refrigerator" are described. Therein, a two-pole magnetic system based on a double-U configuration of permanent magnets is employed and the magneto-caloric refrigerant is confined within eight static regenerator enclosures, which are alternatively magnetized and demagnetized with the rotation of the magnets.

[0010] The prior art designs can be improved. The object of the invention is to create an improved magnetocaloric heat pump and an improved cooling device. In particular it is an object of the invention to optimize different regenerator performances, advantageously while observing costs.

[0011] The object is achieved according to a first aspect of the invention with a magnetocaloric heat pump as defined in claim **1**.

[0012] The invention provides a magnetocaloric heat pump, with a regenerator assembly and at least one rotatable field generator, comprising:

- [0013] a shaft, oriented along a rotation axis and inserted into an axial orifice of a regenerator body of the regenerator assembly and into an axial orifice of at least one generator body of the at least one field generator,
- [0014] the at least one field generator, wherein the at least one generator body is peripherally situated in a periphery of said rotation axis, said generator body comprising a first and a second magnetic ring section, which are located diametrically opposite to each other in relation to the rotation axis, wherein the first and second magnetic ring section comprises a first and second permanent magnet respectively, and each of the first and second permanent magnets of the respective field generator is mounted on a support structure, wherein the support structure comprises a first and a second yoke section with a first and second yoke body, wherein the first and second yoke body are located diametrically opposite to each other in relation to the rotation axis and wherein the field generator is attached to the shaft,
- [0015] the regenerator assembly, wherein the regenerator body is peripherally situated in a periphery of a rotation axis, said regenerator body comprising magnetocaloric material distributed in the regenerator body and wherein the regenerator assembly is arranged around the shaft.

[0016] According to the invention it is provided that

[0017] the regenerator assembly is in form of a ring body and the magnetocaloric material is distributed in the ring body, and

[0018] a magnetic field portion predominantly is guided as an internal magnetic field of the permanent magnets into the first and second yoke body, wherein a further magnetic field portion extends as an external magnetic field of the permanent magnets out of the field generator in the range of the first and second magnetic ring section, such that

[0019] the magnetocaloric material is exerted to the external magnetic field depending on the relative rotational position of the regenerator body and the generator body.

[0020] Thus, the magnetocaloric material (MCM) is distributed regularly, in particular piecewise but equal, in a periphery of the rotation axis. But a magnetic field portion is guided as an internal magnetic field of the permanent magnets predominantly, preferably only into the first and second yoke body, whereas a further magnetic field portion extends as an external magnetic field of the permanent magnets out of the field generator predominantly, preferably only in the range of the first and second magnetic ring section. So to say the magnetic field is external predominantly in the range of the first and second magnetic ring section whereas the magnetocaloric material is distributed regularly. Thus, the support structure prevents an extending of the external magnetic field at the yoke sections except for unavoidable field losses.

[0021] By rotating the field generator with respect to the magnetocaloric material, a magnetization and demagnetization of areas of the magnetocaloric material as described above occurs and leads to a temporary refrigeration of parts of the magnetocaloric material below the ambient temperature. According to the invention the magnetocaloric material is exerted to the external magnetic field. Depending on the relative rotational position of the regenerator body and the generator body, the magnetocaloric material is exerted to the external magnetic field predominantly in the range of the first and second magnetic ring section, i.e. so to say in a high field region of the external magnetic field, whereas the magnetocaloric material that is not in the range of both magnetic ring sections can be regarded as exerted to a low field region of the external magnetic field, which is mainly formed by unavoidable field losses. Thus, a precisely predefined high field region of the external magnetic field can be provided by the invention.

[0022] The invention allows an optimizing of a magnet to MCM ratio and thus minimizes overall device costs for a given performance of the magnetocaloric heat pump. Thereby, costs for a given cooling performance can be reduced as well. Usually in active regenerator assemblies, the cost of magnetocaloric material is small compared to permanent magnet material. Increasing the volume of MCM relative to the field volume can therefore be advantageous.

[0023] A magnetocaloric heat pump according to the first aspect of the invention can advantageously vary the relation between the volume of the magnetocaloric material and the volume that is temporarily applied to the magnetic field of the field generator. The relation between these volumes can thus be optimized.

[0024] Furthermore, the field generator is advantageously formed by causing the first and second yoke section to guide the magnetic field portion as an internal magnetic field of the permanent magnets into the first and second yoke body. This results in a quasi-punctual external magnetic field of the permanent magnets, which extends out of the field generator only at the magnetic body, except for unavoidable field losses. Therefore, a rotation of the field generator leads for a specific part of the magnetocaloric material to a sharply defined field exposure for a preferably short time span, which can be idealized as an on-off-like field behaviour of the external magnetic field of the permanent magnets in relation to the magnetocaloric material. This is advantageous in view of a possible reduction of an amount of permanent magnet material while holding the performance of the regenerator assembly constant, and thus to a simplified and less expensive production.

[0025] A further advantage of the invention according to the first aspect is that an assembling of the regenerator assembly and of the field generator at a shaft, oriented to the ring-axis of the magnetocaloric material, leads to a very compact and robust structure of the magnetocaloric heat pump. The shaft can provide a mechanical connection to a further external device, as for example for rotating the field.

[0026] The claimed magnetocaloric heat pump can be easily adapted to different sizes of a cooling system. For the usual case that the MCM is less expensive than the material of the magnets, a high power can be provided, while the volume of the magnetocaloric heat pump can be reduced. This leads to a reduction of the costs of the magnetocaloric heat pump.

[0027] The use of permanent magnets shows the further advantage that there might be no further electronic means necessary to generate the quasi-punctual external magnetic field of the permanent magnets.

[0028] The MCM within the regenerator body can comprise an outer layer or a shell that protects the MCM against the environment, or which is arranged at the MCM as a by-product of a production process of the magnetocaloric material. In the following, this outer layer or shell is regarded as a part of the MCM for reasons of intelligibility.

[0029] According to a second aspect of the invention a cooling device as defined in claim **13** is provided. According to the invention the cooling device further comprises:

[0030] a magnetocaloric heat pump according to the invention, in particular according to at least one of the claims **1** to **12**,

[0031] a motor, arranged to rotate the field generator with the shaft around the rotation axis,

[0032] at least a first and a second supply pipe system, which are configured and arranged to supply a fluid directing system with fluid,

[0033] at least one hot reservoir and at least one cold reservoir, arranged to provide the at least first and second supply pipe system with fluid and to transport heat out of the cooling device,

[0034] a pump, which is arranged and configured to pump a fluid through the magnetocaloric material.

[0035] The advantages of the cooling device are the same as those of the magnetocaloric heat pump, since the use of the cooling device can be just considered in the context of the corresponding magnetocaloric heat pump.

[0036] The cooling device according to the second aspect of the invention in particular realizes the magnetization and demagnetization of the magnetocaloric material by a rotation of the field generator. One supply pipe of the at least two supply pipe systems supplies the magnetocaloric material with fluid from the at least one cold reservoir. The fluid is heated during the magnetization of the magnetocaloric material and pumped by the pump out of the magnetocaloric material into the at least one hot reservoir. The hot reservoir is configured and arranged to provide a heat exchange with the surrounding, leading to a less heated fluid which is brought into the magnetocaloric material via a further supply pipe of one of both supply pipe systems during the process of demagnetization, and mixed with fluid from the at least one cold reservoir. The mixed fluid is colder after the demagnetization than the fluid within the at least one cold reservoir. Therefore, it is further brought to the at least one cold reservoir, lowering the temperature of the at least one cold reservoir.

[0037] As described above, a process cycle including magnetization and demagnetization as realized by the described cooling device by rotating the field generator leads to a cooling of the at least one cold reservoir.

[0038] According to a third aspect of the invention a method for operating a magnetocaloric heat pump as defined in claim **15** is provided, in particular a magnetocaloric heat pump according to any one of the claims **1** to **12**. The method comprising the steps of:

- **[0039]** providing a regenerator assembly with magnetocaloric material distributed around a rotation axis
- **[0040]** providing at least one field generator wherein a magnetic field portion predominantly is guided as an internal magnetic field of permanent magnets into a first and second yoke body, wherein a further magnetic field portion extends as an external magnetic field of the permanent magnets out of the field generator predominantly in the range of a first and second magnetic ring section, such that
- **[0041]** the magnetocaloric material is exerted predominantly to the external magnetic field depending on the relative rotational position of the regenerator body and the generator body,
- **[0042]** rotating the at least one field generator with respect to the rotation axis for rotating the external magnetic field of the permanent magnets which is applied to the magnetocaloric material,
- **[0043]** providing the magnetocaloric material with a fluid flowing through the magnetocaloric material periodically, wherein a period of fluid supply depends on a rotation frequency of the field generator.

[0044] The advantages of the method for operating a magnetocaloric heat pump are the same as those of the magnetocaloric heat pump, since the magnetocaloric heat pump according to the first aspect implies the method for operating a magnetocaloric heat pump according to the third aspect of the invention.

[0045] In the following, developments of the magnetocaloric heat pump according to the first aspect of the invention will be described.

[0046] In a first development, the field generator comprises a ring shaped structure. In view of the rotation of the field generator during operation of the magnetocaloric heat pump, the ring shaped structure allows a small size of this magnetocaloric heat pump.

[0047] In a development of the magnetocaloric heat pump according to the first aspect of the invention the first and second magnetic ring sections of the at least one field generator each extend along less than 50%, preferably less than 30%, of a total circumference of the respective field generator. Since, in principle, only a quasi-punctual external magnetic field is needed for a required magnetization and demagnetization of the magnetocaloric material, a magnetocaloric heat pump according to this development reduces the used amount of permanent magnet material.

[0048] In a related development of the magnetocaloric heat pump the magnetic field strength of the surrounding magnetic field portion measured over a polar angle of the circumference of a respective field generator, has for each magnetic ring section a full width at half maximum under 60°.

[0049] In another development of the magnetocaloric heat pump, each support structure comprises two field-harmonising sections arranged to attach each yoke body at the respective permanent magnet via the field-harmonising section. The field-harmonising section of this embodiment supports the guiding of the magnetic field portion as an internal magnetic field of the permanent magnets into the first and second yoke body. In a variant of this embodiment, the field-harmonising section is made of the same material as the first and second yoke body and guides the magnetic field portion by its appropriate shape, comprising an increasing cross section in a circumferential direction oriented towards a respective permanent magnet. In a variant, the respective field-harmonising sections are formed by a paramagnetic material or by further permanent magnets.

[0050] In a development of the magnetocaloric heat pump, the field generator comprises basically polyhedral shaped components, in particular basically polyhedral shaped first and second permanent magnets and basically polyhedral shaped first and second yoke bodies. Polyhedral means in this development that components of the field generator comprise straight or curved edges, leading to a preferably rectangular or prismatic shape. In particular the field generator comprises only basically polyhedral shaped components, preferably only rectangular components. In accordance with the first aspect of the invention, the basically polyhedral shaped components are arranged in the periphery of the rotation axis. Basically polyhedral shaped components can be advantageously produced.

[0051] In a development of the magnetocaloric heat pump the first and second yoke bodies are equally shaped and comprise a tailored part to focus the internal magnetic field of the permanent magnets in the magnetic ring sections. In a variant, the tailored part increases its cross section in a direction oriented to the respective permanent magnet. In a further variant, of this development, the first and second permanent magnets are also equally shaped, and the field generator is symmetric with respect to a first and a second axis of symmetry, which are perpendicular to the rotation axis.

[0052] In another development, the magnetocaloric material is distributed in the regenerator body sectionally at an inner periphery line of the regenerator assembly and/or is distributed in the regenerator body sectionally at an outer periphery line of the regenerator assembly. Preferably the magnetocaloric material (MCM) forms at least two MCM-segments, which are separated by respective intermediate sections, and/or wherein an intermediate section has a prismatic shape that allows two rectangular adjacent MCM-segments to contact each other at the tip of the triangular shape. In a variant of this development, the MCM-segments form blocks with even surfaces. If a large amount of magnetocaloric material is exposed to the quasi-punctual external magnetic field of the permanent magnets, a higher cooling power and thus a higher efficiency of the magnetocaloric heat pump can be provided. Therefore it is particularly advantageous to provide a continuously distributed magnetocaloric material at the inner periphery of the regenerator assembly.

[0053] In a further development, the regenerator assembly of the magnetocaloric heat pump comprises at least one regenerator carrier, wherein the at least one regenerator carrier is adapted to carry at least one regenerator body. The regenerator carrier of this development also provides means for the fluid directing system to provide a flow of fluid through the magnetocaloric material. Furthermore, the arranging of the regenerator body within the regenerator carrier can provide an effective way of providing adiabatic conditions, i.e. thermal isolation from the ambient temperature, within the magnetocaloric material during the process cycle.

[0054] In a preferred development, the magnetocaloric heat pump comprises a first and a second field generator wherein at least the first field generator is attached to the shaft, wherein the regenerator assembly is arranged between the first and second field generator. This development is particularly advantageous in view the stronger magnetic field, which is oriented more precisely by the permanent magnets of both field generators. In a variant of this development, only one of both field generators is attached to the shaft, while the other one is connected to the attached field generator via the external magnetic field. This lowers influences of friction within the magnetocaloric heat pump and therefore helps to avoid heat production and power losses. In a further variant of this development, both field generators are formed equally, which can help to reduced costs, while maintaining the described advantages of this development. Furthermore, equally formed field generators can lead to an advantageously distributed external magnetic field that is symmetric with respect to a plane between both field generators that is perpendicular to the rotation axis.

[0055] In another development of the magnetocaloric heat pump, the regenerator assembly and the corresponding regenerator body comprise a ring shaped structure.

[0056] In a further development of the invention according to the first aspect, the magnetocaloric heat pump further comprises an encasement arranged to provide an external access to the shaft. In view of the field generator which rotates during operation of the magnetocaloric heat pump, the encasement protects the rotating field generator from being disturbed by other parts of a surrounding device that uses the magnetocaloric heat pump. The external access to the shaft enables the surrounding device to rotate the field generator and/or to provide a fluid directing system with fluid in order to prepare a magnetic cooling.

[0057] In a development of the magnetocaloric heat pump according to the previous development, the regenerator assembly is coupled to the encasement via the regenerator carrier. Thus, in this development the shaft is arranged to rotate without rotating the regenerator assembly while the regenerator assembly holds its position by being attached to the encasement. In a variant of the development, the fluid directing system is provided within the regenerator assembly and is connected to canals in the shaft by a shaft-rotary valve, which is configured and arranged to provide the regenerator assembly with fluid while the shaft is rotating with respect to the regenerator assembly.

[0058] In a further development of the magnetocaloric heat pump the field generator and a further field generator are attached to the shaft. In a variant of this development, the two field generators are attached to the shaft and the regenerator assembly is arranged between both field generators and attached to the encasement via the regenerator carrier. Thus, in this variant the shaft is arranged to rotate the two field generators without rotating the regenerator assembly and therefore provide a cyclic motion of the two field generators with respect to the regenerator assembly, as required for the previously described magnetocaloric cooling. A further advantage is that the two field generators can be precisely aligned in view of the mechanical connection provided by the shaft, furthermore a magnetic coupling due to a transmittance of a mechanical torque by the magnetic flux between the at least two field generators is provided in all presented developments of the invention according to the first and second aspect that comprise two field generators. The magnetic coupling between the first and the second field generator can advantageously reduce a stress on the shaft.

[0059] Preferably the field generator is attached to the shaft by a first and a second attachment section, wherein the first and a second attachment sections are located diametrically to each other with respect to the rotation axis and/or wherein the first and a second attachment section are arranged to guide the magnetic field portion as an internal magnetic field of the permanent magnets around the shaft. In a variant of this embodiment, the first and second attachment sections are formed by rectangular shaped components. In a further variant, the first and second attachment sections are formed by a paramagnetic material or by a respective further permanent magnet.

[0060] In a development of the magnetocaloric heat pump the shaft further comprises a cogwheel, a gearbox, a pulley or a belt arranged to provide an external access to the shaft. The cogwheel, the gearbox, the pulley or the belt can provide an external access to the shaft for an external motor that rotates a further cogwheel. The magnetocaloric heat pump according to this development can also provide a mechanical connection to an external device.

[0061] In a development of the magnetocaloric heat pump according to the first aspect of the invention, the regenerator assembly comprises at least one further regenerator body arranged around the shaft and further magnetocaloric material. Preferably, the magnetocaloric heat pump of this development comprises an odd number of disc shaped regenerator bodies. Thus, in this development, a larger volume of the magnetocaloric material is exposed to the quasi-punctual external magnetic field of the field generator than in the case of a single regenerator body. More regenerator bodies can lead to a more effective process cycle and to a larger homogeneity of a resulting heat flow of the magnetocaloric heat pump. Using more regenerator bodies can also enlarge a volume of refrigerated fluid during a process cycle, since a larger volume of magnetocaloric material can be surrounded by the fluid. The multiple regenerator bodies of this development are preferably located between a first and a second field generator. In a further preferred variant, a plurality of field generators is provided and each generator body of the multiple regenerator bodies is arranged between a respective pair of field generators. The number of regenerator bodies and a detailed configuration can change based on possible requirements for minimizing a magnetic torque which might be generated by a non-homogeneity of a relative permeability of the multiple regenerator bodies and for optimizing a cooling cycle, a cooling power and an efficiency of the magnetocaloric heat pump. In particular, by choosing the number of regenerator bodies, it can be prevented that both magnets are at the same time in a position relative to a magnetocaloric material, where no external magnetic field is exerted to magnetocaloric material. In a variant of this development, gaps between the multiple regenerator bodies or between multiple regenerator carriers comprising the regenerator bodies are filled by an insulating material which might comprises a similar relative permeability as the multiple regenerator bodies. This can advantageously reduce a magnetic torque between the multiple regenerator bodies. In a further variant of the development, the number of the multiple regenerator bodies is odd, which means that the number of further regenerator bodies is even. This can also advantageously reduce a magnetic torque between the multiple regenerator bodies.

[0062] The providing of multiple field generators at opposite directions of the magnetocaloric material can also be described as an arranging of the regenerator assembly within a gap between the two field generators. The gap has to be small enough to ensure that the magnetocaloric material within the regenerator carrier of the regenerator assembly is applied to the external field of the field generators.

[0063] To enable a proper choice of appropriate magnetocaloric material, the whole content of the international patent application PCT/EP2010/061025 is herewith included into this description.

[0064] The heat pump can further be used for heating purposes in view of the feature that heat is pumped out of a system and therefore can increase a mean temperature of a surrounding system.

[0065] In the following, developments of the cooling device according to the second aspect of the invention will be described.

[0066] In a first development of the cooling device each part of the magnetocaloric material is to applied to the quasi-punctual external magnetic field during a single rotation of the field generator for a period of time that is shorter than half of the duration of the single rotation. Since only a quasi-punctual external magnetic field is needed for a required magnetization and demagnetization of the magnetocaloric material, a cooling device according to this development reduces the used amount of permanent magnet material.

[0067] In a development of the cooling device according the second aspect of the invention the cooling device the at least one pump is arranged and configured to provide a flow circulation of the fluid through the magnetocaloric material. The pump can enable the cooling device to speed up the process cycle of magnetization and demagnetization of the magnetocaloric material, since an active pumping of the fluid into the magnetocaloric material leads to a faster temperature transfer of hot or cold fluid into the respective reservoir and back into the regenerator assembly.

[0068] In a preferred development of the cooling device, the cooling device further comprises at least four valves, comprising two active valves arranged to control the first pump and two passive valves arranged to control and maintain a supply of the fluid directing system with fluid, in particular wherein the two active valves are configured to be activated mechanically, preferably by a camshaft system, and/or the two valves are configured to be activated magnetically. As described above, the pumping of hot fluid out of the magnetocaloric material into the at least one hot reservoir is provided by the pump as a first part of the flow circulation. The two passive valves are furthermore arranged to control an inflow and an outflow of the cold reservoir. The two active valves are arranged to control the first part of the flow circulation and thus to regulate an inflow and an outflow of the hot reservoir. The use of active valves is advantageous in view of the high pressure at the hot reservoir. An advantage of the use of a valve is a reduction of an undesired backflow of hot or cold fluid into the magnetocaloric material. Furthermore valves provide a directed flow, as it is required for the process cycle of the magnetocaloric heat pump during processing. In a variant of this development, the two active valves are configured to be activated mechanically, preferably by a camshaft, and/or magnetically. A magnetically activated valve can take advantage of the alternating external magnetic field of the field generator. A further advantage of a magnetically activated valve is that it might reduces friction forces that occur during a mechanical activation. A magnetically activated valve can be advantageously coupled to the motor rotating the field generator, since a position of the poles of the permanent magnet and a position of the active valves are correlated in view of the desired process cycle of the cooling device. A use of a camshaft valve is particularly advantageous, since it is less complex than a rotational valve and can therefore provide a longer lifetime and a higher reliability.

[0069] In a further development, a first heat exchanger is mechanically connected with the at least one hot reservoir. The first heat exchanger can improve the heat exchange between hot reservoir and surrounded environment. Therefore, the first heat exchanger can lead to an improved overall cooling of the cooling device. In a further development, a second heat exchanger is mechanically connected to the at least one could reservoir. The second heat exchanger can improve the heat exchange between cold reservoirs and surrounded cooling device. Therefore, the second heat exchanger can lead to an improved overall cooling of the cooling device. In a variant of this development, a first and a second fan are arranged on the first and the second heat exchanger. Thus, in this variant, a transfer of heat is improved.

[0070] In a development of the cooling device according to the second aspect of the invention, the cooling device comprises a first and a second hot reservoir and a first and a second cold reservoir. The cooling device according to this embodiment is arranged to provide a second hot reservoir for transferring the hot fluid of the first hot reservoir into the second hot reservoir after executing a heat exchange with the surrounding, as might be performed by the first heat exchanger. Afterwards the less heated fluid of the second hot reservoir flows back into the magnetocaloric material via the second of the at least two supply pipes. Furthermore, the cooling device according to this embodiment is arranged to provide a second cold reservoir for transferring the cold fluid of the first cold reservoir into the second cold reservoir after executing a heat exchange with the surrounding cooling device, as might be performed by the second heat exchanger. Afterwards the less cold fluid of the second cold reservoir flows back into the magnetocaloric material via the first of the at least two supply pipes, and a new process cycle starts.

Thus, a cooling device according to this development provides a more effective cooling of the cooling device than a cooling device with two reservoirs.

[0071] In a further development of the cooling device, the cooling device comprises a first heat exchanger, arranged and configured to provide a second hot reservoir with the hot fluid of a first hot reservoir after a first heat exchange with a first surrounding, and a second heat exchanger, arranged and configured to provide a second cold reservoir with a cold fluid of a first cold reservoir after a second heat exchange with a second surrounding. In this development, the first surrounding can be an ambient room, while the second surrounding can be a container to cool by the cooling device. In a variant of this development, the first surrounding and the second surrounding are identical.

[0072] In a further development of the cooling device, at least one cold reservoir is an integrated cold reservoir arranged inside the regenerator carrier. Such an integrated cold reservoir can lead to a smaller cooling device and/or to a faster flow circulation.

[0073] The invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

[0074] In the following the drawing shows in:

[0075] FIG. **1** an exploded view of a first embodiment of a magnetocaloric heat pump according to the first aspect of the invention, wherein the magnetocaloric heat pump comprises a first and a second field generator and an encasement,

[0076] FIG. **2** an illustration of the first embodiment of the magnetocaloric heat pump according to the first aspect of the invention, wherein the magnetocaloric heat pump comprises a first and a second field generator and an encasement,

[0077] FIG. **3** an illustration of the first embodiment of the magnetocaloric heat pump according to the first aspect of the invention, wherein the generator body is not shown for reasons of visualization,

[0078] FIG. **4** a field distribution for the first embodiment of the magnetocaloric heat pump according to the first aspect of the invention,

[0079] FIG. **5** a schematic illustration of a first embodiment of a cooling device according to the second aspect of the invention,

[0080] FIG. **6** a schematic illustration of a process cycle of a further embodiment of a cooling device according to the second aspect of the invention,

[0081] FIG. **7** a block diagram of a method for operating a magnetocaloric heat pump according to the third aspect of the invention.

[0082] FIG. **1** shows an exploded view of a first embodiment of a magnetocaloric heat pump **100** according to the first aspect of the invention, wherein the magnetocaloric heat pump **100** comprises a first and a second field generator **150**, **155** and an encasement **170**, **175**.

[0083] The magnetocaloric heat pump **100** comprises a regenerator assembly **110**, comprising a magnetocaloric material **120** distributed in a regenerator body **130** which is situated in a periphery of a rotation axis **125** and is formed as a ring body. The regenerator body **130** is furthermore arranged in a regenerator carrier **135** comprising a fluid directing system **140**, which comprises a radial portion **145** directing fluid through the magnetocaloric material **120** into a direction perpendicular to the rotation axis **125**. Furthermore, there are a first and a second field generator **150**, **155**, each comprising a peripheral generator body **150'**, **155'** which is situated in a periphery of said rotation axis **125**, said generator body **150'**, **150"** comprising a first and a second, preferably diametrically opposed located, magnetic ring section **151'**, **151"**, **156'**, **156"** each of the first and second magnetic ring section formed by a permanent magnet **152'**, **152"**, **157'**, **157"**, and each of the first and second permanent magnet of a respective field generator **150**, **155** is mounted on a support structure **153**, **158** comprising a first and a second, preferably diametrically opposed located, yoke section **153'**, **153"**, **158'** with a first and second yoke body **154'**, **154"**, **159'**, wherein the first and second field generators **150**, **155** are rotatably arranged at opposite directions of the magnetocaloric material **120** on the rotation axis **125**.

[0084] As a connection between these parts of the magnetocaloric heat pump **100**, a shaft **160** is shown, which is oriented along the rotation axis **125** and arranged to be inserted into the regenerator assembly **110** and into the first and second field generators **150**, **155** and comprising at least a first and a second canal **164**, **168** arranged to provide the fluid directing system **140** with fluid.

[0085] It is furthermore depicted that the magnetocaloric heat pump **100** of this embodiment comprises an encasement **170**, **175** with a first and a second opening **172**, **177** arranged to provide an external access to the shaft **160** via a cogwheel **180**.

[0086] The first and second field generator **150**, **155**, the regenerator assembly **110** and the regenerator body **130** of the depicted embodiment show a ring shaped structure. The regenerator assembly **110** can in particular be understood as a wheel or ring that contains all regenerator bodies and all magnetocaloric material. Furthermore, the first and second field generators **150**, **155** can in particular be understood as a first and a second complete disc that contain the magnetic ring sections **151'**, **151"**, **156'**, **156"** formed by the permanent magnets **152'**, **152"**, **157'**, **157"**.

[0087] The magnetocaloric material **120** comprises gadolinium.

[0088] A shape of the yoke bodies **154'**, **154"**, **159'** causes a guiding of a magnetic field portion as an internal magnetic field of the permanent magnets **152'**, **152"**, **157'**, **157"** into the first and second yoke body **154'**, **154"**, **159'**, while a further magnetic field portion as a quasi-punctual external magnetic field of the permanent magnets **152'**, **152"**, **157'**, **157"** extends out of the respective field generator **150**, **155** predominantly, preferably only at the magnetic ring section **151'**, **151"**, **156'**, **156"**.

[0089] As also shown in FIG. **1**, the first and second magnetic ring section **151'**, **151"**, **156'**, **156"** of each field generator **150**, **155** form less than 50% of a circumference of the respective field generator **150**, **155**.

[0090] Furthermore, each of the first and second field generator **150**, **155** comprises four field-harmonising sections **192**, **194**, **196**, **198** (just labelled at the first field generator **150** for reasons of visualization) arranged to attach each yoke body **154'**, **154"**, **159'**, **159"** at the respective permanent magnet **152'**, **152"**, **157'**, **157"** via the field-harmonising section **192**, **194**, **196**, **198**.

[0091] As also depicted in FIG. **1**, the first and second field generator **150**, **155** are each attached to the shaft **160** by a first and a second diametrically opposed attachment section **193**, **197** (not shown for the second field generator **155**) arranged to guide the magnetic field portion as an internal magnetic field of the permanent magnets **152'**, **152"**, **157'**, **157"** around the shaft **160**. The attachment sections **193**, **197** as well as the field-harmonising sections **192**, **194**, **196**, **198**

form polyhedral shaped components of the first and second field generator **150**, **155** and are each formed by a further permanent magnet.

[0092] The respective first and second yoke body **154'**, **154"**, **159'** in the first and second yoke section **153'**, **153"**, **158'** are equally shaped and comprise each a first and a second tailored part **154*t*'**, **154*t*"** (other tailored parts not labelled for reasons of visualization) to focus the internal magnetic field of the permanent magnets in the magnetic ring sections **151'**, **151"**, **156'**, **156"**.

[0093] The magnetocaloric material **120** is distributed sectionally and thereby forms MCM segments **122**, which are separated by respective intermediate sections **124**, which have a respective wedge shape that causes two respective adjacent MCM segments **122** to contact each other.

[0094] It is not shown in FIG. **1** that the generator carrier **135** is mechanically connected with the shaft **160** by a shaft-rotary valve, which is configured and arranged to provide the regenerator assembly **110** and especially the fluid directing system **140** with fluid while the shaft **160** is rotating with respect to the regenerator assembly **110**.

[0095] The process of cooling with the shown magnetocaloric heat pump **100** will be elucidated in the context of FIG. **4**, where a schematic illustration of a process cycle is depicted.

[0096] In a not shown embodiment of the magnetocaloric heat pump according to the first aspect of the invention, at least two regenerator bodies, in particular an odd number of regenerator bodies are used within the magnetocaloric heat pump. These at least two regenerator bodies are arranged between the first and second field generator according to a respective rotation axis.

[0097] FIG. **2** shows an illustration of the first embodiment of the magnetocaloric heat pump **100** according to the first aspect of the invention, wherein the magnetocaloric heat pump **100** comprises a first and a second field generator **150**, **155** and an encasement **170**, **175**.

[0098] In contrast to the exploded view shown in FIG. **1**, an assembled state of the magnetocaloric heat pump **100** is depicted in FIG. **2**. Thus, the magnetocaloric material **120** is surrounded by the regenerator carrier **135** and can therefore not be seen in this illustration. It is shown, that the regenerator assembly **110** is attached to the encasement **170**, **175** via the regenerator carrier **135**. Furthermore, the encasement **170**, **175** is translucent and thus allows recognizing the two field generators **150**, **155** which are attached to the shaft **160**. Therefore, in the shown embodiment, the shaft **160** is arranged to rotate the first and second field generator **150**, **155** without rotating the regenerator assembly **110** and therefore provides a cyclic motion of the first and second field generator **150**, **155** with respect to the regenerator assembly **110**, as required for the magnetocaloric cooling as described above. Furthermore, in this embodiment of the magnetocaloric heat pump **100** the first and second field generator **150**, **155** can be precisely aligned in view of the mechanical connection provided by the shaft **160**, although a magnetic coupling due to a transmittance of a mechanical torque by the magnetic flux between the first and second field generator **150**, **155** is provided.

[0099] Although specifications of magnetocaloric heat pumps according to the first aspect of the invention can vary according the respective surrounding cooling device, in the following are given the specifications of the depicted magnetocaloric heat pump **100** to describe the shown embodiment thoroughly:

[0100] The magnetocaloric heat pump **100** has an overall diameter between 100 mm and 500 mm, preferably 260 mm, and an overall height between 80 mm and 250 mm, preferably 160 mm. The regenerator body **130** shows a height between 25 mm and 80 mm, preferably 40 mm. The magnetocaloric material has a height between 10 mm and 40 mm, preferably 20 mm, an inner diameter between 50 mm and 500 mm, preferably 160 mm, and an outer diameter between 100 mm and 600 mm, preferably 240 mm. Furthermore a performance of the magnetocaloric heat pump **100** according to the depicted embodiment can be estimated to show a maximal cooling power Q_C of about 1 KW, for an average high field of the first and second field generator **150**, **155** of about 1 T and an average low field of about 0 T.

[0101] FIG. **3** shows an illustration of the first embodiment of the magnetocaloric heat pump **100** according to the first aspect of the invention, wherein the generator body **130** is not shown for reasons of visualization. It is shown, how the magnetocaloric material **120** is arranged with respect to the first and second field generator **150**, **155**.

[0102] The quasi-punctual external magnetic field of the permanent magnets **152'**, **152"**, **157'** extends out of the field generator **150**, **155** predominantly, preferably only at the magnetic ring section **151'**, **151"**, **156'**, and is thereby directly applied to the MCM segments **122** formed by the magnetocaloric material **120**.

[0103] FIG. **4** shows a field distribution for the first embodiment of the magnetocaloric heat pump **100** according to the first aspect of the invention.

[0104] The depicted grey scale tone is proportional to a magnetic field strength that is present due to the permanent magnets **152'**, **152"**, while a dark tone means less magnetic field strength and a pale tone means a high magnetic field strength. The quasi-punctual external magnetic field **410**, **415** of the permanent magnets **152'**, **152"** extends out of the field generator **150** predominantly, preferably only at the magnetic ring section **151'**, **151"**. The yoke sections **153'**, **153"** are formed to guide a magnetic field portion as an internal magnetic field **420**, **425** of the permanent magnets into the first and second yoke body **154'**, **154"**, as illustrated by FIG. **4**.

[0105] It is furthermore shown in FIG. **4** that the field generator **150** comprises a first and a second diametrically opposed attachment section **193**, **197**, which is arranged to guide the magnetic field portion as an internal magnetic field **430** of the permanent magnets **152'**, **152"** around the shaft **160**.

[0106] FIG. **5** shows a schematic illustration of a first embodiment of a cooling device **500** according to the second aspect of the invention.

[0107] The cooling device **500** comprises the embodiment of the magnetocaloric heat pump **100** previously depicted in FIG. **1** and FIG. **2**. Furthermore, a motor **510** is shown, which is arranged to rotate the first and second field generator **150**, **155** of the magnetocaloric heat pump **100** according to the rotation axis **125**. A first and a second supply pipe system, comprising a first and second pipe **522**, **524** of the first supply pipe system and a first and second supply pipe **526**, **528** of the second supply pipe system, configured to supply the fluid directing system (shown in FIG. **1**) with fluid are given as connection between a cold reservoir **530** and the regenerator assembly **110** and between the hot reservoir **540** and the regenerator assembly **110**. A pump **550** is arranged and configured to pump a hot fluid out of the magnetocaloric material **120**.

[0108] The cooling device **500** provides a magnetization and demagnetization of the magnetocaloric material **120** by a rotation of the first and second field generator **150**, **155**. The first supply pipe **522** of the first supply pipe system supplies the magnetocaloric material **120** with fluid from the cold reservoir **530**. The fluid is heated during the magnetization of the magnetocaloric material **120** and pumped by the pump **550** out of the magnetocaloric material **120** through the first supply pipe **526** of the second supply pipe system into the hot reservoir **540**. The hot reservoir **540** is configured and arranged to provide a heat exchange with the surrounding, leading to a less heated fluid which is brought into the magnetocaloric material **120** via the second supply pipe **528** of the second supply pipe system during the process of demagnetization, and mixed with fluid from the cold reservoir **530**. The mixed fluid is colder after the demagnetization than the fluid within the cold reservoir **530**. Therefore, it is further brought to the cold reservoir **530** via the second supply pipe **524** of the first supply pipe system, lowering the temperature of the cold reservoir **530**.

[0109] Thus, a process cycle including magnetization and demagnetization as realized by the depicted cooling device **500** by rotating the first and second field generator **150**, **155**, leads to a further cooling of the cold reservoir **530**.

[0110] In a not shown embodiment of the cooling device, the cooling device further comprises four valves, comprising two active valves arranged to control the first pump and two passive valves arranged to control and maintain a supply of the fluid directing system with the fluid. In a further not shown embodiment, the two active valves are configured to be activated mechanically, preferably by a camshaft system, and/or magnetically.

[0111] FIG. **6** shows a schematic illustration of a process cycle **600** of a further embodiment of a cooling device **610** according to the second aspect of the invention. Many parts of the cooling device **610** as well as of the included magnetocaloric heat pump **100** are removed in order to illustrate the crucial steps of the process cycle **600**.

[0112] The cooling device **610** comprises a first and a second hot reservoir **622**, **626** and a first and a second cold reservoir **632**, **636**. The cooling device **610** according to this embodiment is arranged to provide a second hot reservoir **626** for transferring the hot fluid of the first hot reservoir **622** into the second hot reservoir **626** after executing a heat exchange with the surrounding by a first heat exchanger **642**. Afterwards the less heated fluid of the second hot reservoir **626** flows back into the magnetocaloric material **650** via a first set of a first and a second supply pipe **662**, **666**. Afterwards the fluid flows into the first cold reservoir **632**. The cooling device **610** according to this embodiment is arranged to provide the second cold reservoir **636** for transferring the cold fluid of the first cold reservoir **632** into the second cold reservoir **636** after executing a heat exchange with the surrounding cooling device by the second heat exchanger **646**. Afterwards, the less cold fluid of the second cold reservoir flows back into the magnetocaloric material **650** via a second set of a first and a second supply pipe **672**, **676**. After the magnetization of the magnetocaloric material **650**, the heated fluid is pumped into the first hot reservoir **622** and a new process cycle **600** starts. Thus, the cooling device **610** provides an effective cooling of a surrounding of the second heat exchanger **646**.

[0113] FIG. **7** shows a block diagram of a method for operating a magnetocaloric heat pump according to the third aspect of the invention.

[0114] The method comprises as a first step **710** a providing of a heat pump according to the first aspect of the invention.

[0115] As a subsequent step **720**, the method comprises a guiding of a magnetic field portion as an internal magnetic field of the permanent magnets into the first and second yoke body.

[0116] Afterwards, a rotating of the field generator with respect to the rotation axis for rotating the quasi-punctual external magnetic field of the permanent magnets which is applied to the magnetocaloric material, forms a third step **730** of the method.

[0117] A last step **740**, the method comprises a providing of the magnetocaloric material with a fluid flowing through the magnetocaloric material periodically, wherein a period of fluid supply depends on a rotation frequency of the field generator.

LIST OF REFERENCE SIGNS

[0118] **100** magnetocaloric heat pump
[0119] **110** regenerator assembly
[0120] **120** magnetocaloric material
[0121] **122** MCM segment
[0122] **124** intermediate section
[0123] **125** rotation axis
[0124] **130** regenerator body
[0125] **135** regenerator carrier
[0126] **140** fluid directing system
[0127] **145** radial portion
[0128] **150** first field generator
[0129] **150'** first generator body
[0130] **151'** first magnetic ring section of the first field generator
[0131] **151"** second magnetic ring section of the first field generator
[0132] **152'** first permanent magnet of the first field generator
[0133] **152"** second permanent magnet of the first field generator
[0134] **153** support structure of the first field generator
[0135] **153'** first yoke section of the first field generator
[0136] **153"** second yoke section of the first field generator
[0137] **154'** first yoke body of the first field generator
[0138] **154"** second yoke body of the first field generator
[0139] **154*t*'** first tailored part
[0140] **154*t*"** second tailored part
[0141] **155** second field generator
[0142] **155'** second generator body
[0143] **156'** first magnetic ring section of the second field generator
[0144] **156"** second magnetic ring section of the second field generator
[0145] **157'** first permanent magnet of the second field generator
[0146] **157"** second permanent magnet of the second field generator
[0147] **158** support structure of the second field generator
[0148] **158'** first yoke section of the second field generator

[0149] **158"** second yoke section of the second field generator

[0150] **159'** first yoke body of the second field generator

[0151] **159"** second yoke body of the second field generator

[0152] **160** shaft

[0153] **164** first canal of the shaft

[0154] **168** second canal of the shaft

[0155] **170** front part of the encasement

[0156] **172** first opening

[0157] **175** back part of the encasement

[0158] **177** second opening

[0159] **180** cogwheel

[0160] **192**, **194**, **196**, **198** field-harmonising sections of the first field generator

[0161] **193** first attachment section

[0162] **197** second attachment section

[0163] **410** quasi-punctual external magnetic field of the first permanent magnet

[0164] **415** quasi-punctual external magnetic field of the second permanent magnet

[0165] **420** internal magnetic field of the first yoke body

[0166] **425** internal magnetic field of the second yoke body

[0167] **430** internal magnetic field guided around the shaft

[0168] **500** cooling device

[0169] **510** motor

[0170] **522** first supply pipe of the first supply pipe system

[0171] **524** second supply pipe of the first supply pipe system

[0172] **526** first supply pipe of the second supply pipe system

[0173] **528** second supply pipe of the second supply pipe system

[0174] **530** cold reservoir

[0175] **540** hot reservoir

[0176] **550** pump

[0177] **600** process cycle

[0178] **610** cooling device according to a further embodiment

[0179] **622** first hot reservoir of the further embodiment

[0180] **626** second hot reservoir of the further embodiment

[0181] **632** first cold reservoir of the further embodiment

[0182] **636** second cold reservoir of the further embodiment

[0183] **642** first heat exchanger

[0184] **646** second heat exchanger

[0185] **650** magnetocaloric material of the further embodiment

[0186] **662** first supply pipe of the first set

[0187] **666** second supply pipe of the first set

[0188] **672** first supply pipe of the second set

[0189] **676** second supply pipe of the second set

[0190] **710** first step of the method

[0191] **720** subsequent step of the method

[0192] **730** third step of the method

[0193] **740** last step of the method

1. A magnetocaloric heat pump with a regenerator assembly and at least one rotatable field generator, comprising:

a shaft, oriented along a rotation axis and inserted into an axial orifice of a regenerator body of the regenerator assembly and into an axial orifice of at least one generator body of the at least one field generator,

the at least one field generator, wherein the at least one generator body is peripherally situated in a periphery of said rotation axis, said generator body comprising a first and a second magnetic ring section, which are located diametrically opposite to each other in relation to the rotation axis, wherein the first and second magnetic ring section comprises a first and second permanent magnet respectively, and each of the first and second permanent magnets of the respective field generator is mounted on a support structure, wherein the at least one field generator is attached to the shaft,

the regenerator assembly, wherein the regenerator body is peripherally situated in a periphery of a rotation axis, said regenerator body comprising magnetocaloric material distributed in the regenerator body and wherein the regenerator assembly is arranged around the shaft,

wherein:

the support structure comprises a first and a second yoke section with a first and second yoke body, wherein the first and second yoke body are located diametrically opposite to each other in relation to the rotation axis,

the regenerator body is in form of a ring body and the magnetocaloric material is distributed regularly, in particular piecewise but equal, in the ring body, and

a magnetic field portion predominantly is guided as an internal magnetic field of the permanent magnets into the first and second yoke body, wherein a further magnetic field portion extends as an external magnetic field of the permanent magnets out of the field generator in the range of the first and second magnetic ring section, such that

the magnetocaloric material is exerted to the external magnetic field depending on the relative rotational position of the regenerator body and the generator body.

2. The magnetocaloric heat pump according to claim **1**, wherein the first and second magnetic ring sections of the at least one field generator each extend along less than 50% of a total circumference of the respective field generator.

3. The magnetocaloric heat pump according to claim **1**, wherein each support structure comprises two field-harmonising sections arranged to attach each yoke body at the respective permanent magnet via the field-harmonising section.

4. The magnetocaloric heat pump according to claim **1**, wherein the field generator comprises polyhedral shaped components.

5. The magnetocaloric heat pump according to claim **1**, wherein the first and second yoke bodies are equally shaped and comprise a tailored part to focus the internal magnetic field of the permanent magnets in the magnetic ring sections.

6. The magnetocaloric heat pump according to claim **1**, wherein the magnetocaloric material is distributed in the regenerator body sectionally at an inner periphery line of the regenerator assembly and/or is distributed in the regenerator body sectionally at an outer periphery line of the regenerator assembly.

7. The magnetocaloric heat pump according to claim **6**, wherein the magnetocaloric material (MCM) forms at least two MCM-segments, which are separated by respective intermediate sections, and/or wherein an intermediate section has a prismatic shape that allows two rectangular adjacent MCM-segments to contact each other at the tip of the triangular shape.

8. The magnetocaloric heat pump according to claim **1**, wherein the regenerator assembly comprises at least one regenerator carrier, wherein the at least one regenerator carrier is adapted to carry at least one regenerator body.

9. The magnetocaloric heat pump according to claim **1**, further comprising a first and a second field generator, wherein at least the first field generator is attached to the shaft and wherein the regenerator assembly is arranged between the first and second field generator.

10. The magnetocaloric heat pump according to claim **1**, further comprising an encasement arranged to provide an external access to the shaft.

11. The magnetocaloric heat pump according to claim **10**, wherein the regenerator assembly is coupled to the encasement via the regenerator carrier.

12. The magnetocaloric heat pump according to claim **1**, wherein the field generator is attached to the shaft by a first and a second attachment section, wherein the first and second attachment sections are located diametrically to each other with respect to the rotation axis and/or wherein the first and second attachment sections are arranged to guide the magnetic field portion as an internal magnetic field of the permanent magnets around the shaft.

13. The magnetocaloric heat pump according to claim **1**, wherein the regenerator assembly comprises at least one further regenerator body arranged around the shaft and further magnetocaloric material.

14. A cooling device, comprising

the magnetocaloric heat pump according to claim **1**,

a motor, arranged to rotate the field generator with the shaft around the rotation axis,

at least a first and a second supply pipe system, which are configured and arranged to supply a fluid directing system with fluid,

at least one hot reservoir and at least one cold reservoir, arranged to provide the at least first and second supply pipe system with fluid and to transport heat out of the cooling device, and

a pump, which is arranged and configured to pump a fluid through the magnetocaloric material.

15. The cooling device according to claim **14**, further comprising at least four valves, comprising two active valves arranged to control the pump and two passive valves arranged to control and maintain a supply of the fluid directing system with fluid.

16. A method of operating a magnetocaloric heat pump, the method comprising:

providing a regenerator assembly with magnetocaloric material distributed around a rotation axis,

providing at least one field generator wherein a magnetic field portion predominantly is guided as an internal magnetic field of permanent magnets into a first and second yoke body, wherein a further magnetic field portion extends as an external magnetic field of the permanent magnets out of the field generator predominantly in the range of a first and second magnetic ring section, such that

the magnetocaloric material is exerted predominantly to the external magnetic field depending on the relative rotational position of the regenerator body and the generator body,

rotating the at least one field generator with respect to the rotation axis for rotating the external magnetic field of the permanent magnets which is applied to the magnetocaloric material, and

providing the magnetocaloric material with a fluid flowing through the magnetocaloric material periodically, wherein a period of fluid supply depends on a rotation frequency of the field generator.

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