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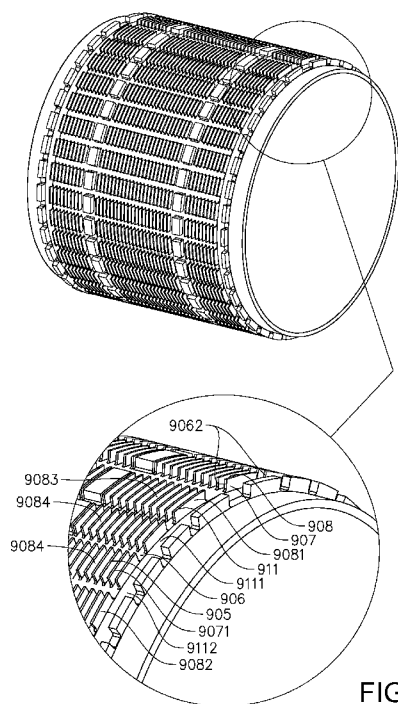


FIG. 5

(57) Abstract: The invention provides a heat exchanger comprising at least one fluid inlet (902) and at least one fluid outlet (903), the heat exchanger comprising a bottom portion (9112), a top portion (912), and a plurality of walls (9082), the walls (9082) being arranged between the bottom portion (9112) and the top portion (912) such that a plurality of channels (9083) are formed between the bottom portion (9112), the top portion (912) and pairs of adjacent walls (9082), wherein the channels (9083) are arranged to guide a fluid from the fluid inlet to the fluid outlet, characterized in that the walls (9082) present a plurality of interruptions (9062), each interruption (9062) fluidly connecting two adjacent channels (9083) to each other.



A Heat Exchanger and a Working Machine

TECHNICAL FIELD

- 5 The invention relates to a heat exchanger. The invention also relates to a motor and transmission combination, a working machine, and a method for manufacturing a heat exchanger.

The invention is applicable on working machines within the fields of industrial construction
10 machines or construction equipment, in particular wheel loaders. Although the invention will be described with respect to a wheel loader, the invention is not restricted to this particular machine, but may also be used in other working machines such as articulated haulers, excavators and backhoe loaders. The invention can also be applied in heavy-duty vehicles, such as trucks, buses and construction equipment. The invention may also
15 be used in other vehicles such as cars. In addition, the invention may be used in other technical fields where heat exchanging functions are required.

BACKGROUND

- 20 A working machine, e.g. a wheel loader or an articulated hauler, is usually provided with a bucket, container or other type of implement for digging, carrying and/or transporting a load.

For example, a wheel loader has a lift arm unit for raising and lowering an implement,
25 such as a bucket. The lift arm comprises hydraulic cylinders for movement of a load arm and the implement attached to the load arm. Usually a pair of hydraulic cylinders is arranged for raising the load arm and a further hydraulic cylinder is arranged for tilting the implement relative to the load arm.

- 30 In addition, the working machine is often articulated frame-steered and has a pair of hydraulic cylinders for turning/steering the working machine by pivoting a front section and a rear section of the working machine relative to each other.

The hydraulic system generally further comprises at least one hydraulic pump, which is
35 arranged to supply hydraulic power, i.e. hydraulic flow and hydraulic pressure, to the

hydraulic cylinders. The hydraulic pump is driven by a power source, such as an internal combustion engine or an electric motor.

In a traditional driveline for a working machine, an internal combustion engine, usually a diesel engine, is provided, as well as a transmission, drive shafts, and wheel axle sets with hubs. However, alternative working machine drivelines may be considered, e.g. electric hybrid drivelines, with parallel or series hybrid configurations, or purely electric drivelines. A series electric hybrid driveline can comprise an internal combustion engine, a generator, an electric energy storage arrangement, power electronics, as well as electric motors and transmissions in the wheel hubs. Such hub motors and transmission combinations will require cooling as well as lubrication.

US20110011203 describes an in-wheel motor drive for an electric car, in which oil for a transmission of the drive is pumped through axial oil paths in a casing for a motor of the drive. A circumferentially extending cooling water path is also provided in the casing. The axial oil paths are provided by tube like partition members extending axially through the cooling water path. It is suggested that the cooling water path contributes to cooling the oil as well as the motor. However, this cooling arrangement, with the oil paths, may be difficult to manufacture. In addition, cooling oil effectively is difficult, and there is a desire to improve the heat transfer from oil in a heat exchanger.

US20140069099 describes an electric machine for a hybrid drive for a motor vehicle. In a housing of the machine a cooling fluid is arranged to flow in a circumferential direction in a meandering manner whereby the fluid is guided alternatingly through pairs of channels and connecting sections where the flows in the channel pairs are joined. It is suggested that this gives a transport of heat away from the central plane of the machine. However, the suggested design seems to provide a high flow resistance. Also, this arrangement may also provide manufacturing challenges.

SUMMARY

An object of the invention is to improve the heat transfer capacity of a heat exchanger, in particularly a heat exchanger for a working machine hub motor and transmission combination. It is further an object of the invention to improve the heat transfer from an oil

in a heat exchanger. In addition, it is an object of the invention to provide an improved heat exchanger which is easy to manufacture.

The objects are achieved by a heat exchanger according to claim 1. Thus, an aspect of the invention provides a heat exchanger comprising at least one fluid inlet and at least one fluid outlet, the heat exchanger comprising a bottom portion, a top portion, and a plurality of walls, the walls being arranged between the bottom portion and the top portion such that a plurality of channels are formed between the bottom portion, the top portion and pairs of adjacent walls, wherein the channels are arranged to guide a fluid from the fluid inlet to the fluid outlet, characterized in that the walls present a plurality of interruptions, each interruption fluidly connecting two adjacent channels to each other.

Said aspect of the invention may provide an advantageous turbulent flow of the fluid in the channels. The aspect is particularly advantageous where the fluid is oil, e.g. where the oil provides a double function of cooling and lubricating, as exemplified below. Oil flows are not inherently turbulent at low flow rates, and the lack of turbulence may impede an effective heat transfer from the oil. As the oil in adjacent channels reaches a wall interruption this may trigger a turbulence in the oil flow. More specifically, upon reaching an interruption, the oil will tend to flow in spirals since the oil is forced to slow down. The resulting turbulence will considerably improve the heat transfer from the oil.

In addition, the walls may provide a very high wet area, further facilitating the heat transfer in the heat exchanger. Also, the heat exchanger according to said aspect of the invention may combine relative large heat transferring areas with small flow losses due to the arrangement of the walls with interruptions. Further, the walls may provide a double function of guiding the fluid and provide supports for the top portion against the bottom portion.

In some embodiments the bottom portion and at least a portion of the walls are integrated to form what is herein referred to as a topological member. It should be noted that the wordings bottom portion and top portion are appellations only and do not imply any limitation regarding the location of the bottom and top portions in relation to each other and the surroundings.

In preferred embodiments the walls form, between the interruptions, fins, whereby the fins are arranged in a plurality of rows extending at least partly transversely to the walls. Pairs of adjacent fins may form with the bottom portion respective depressions between them, whereby the depressions form with the top portion respective passages, as described
5 further below. It should be noted that each wall preferably has a main extension along the bottom portion. A row extending transversely to a wall means that the row extends transversely to the wall main extension and along the bottom portion. The row extending at least partly transversely to the wall means that the extension of the row has at least a component which is transverse to the wall main extension.

10

A plurality of cavities may be formed between the bottom portion, the top portion and pairs of adjacent rows of fins. Thus the cavities may be formed by wall interruptions which are aligned transversely to the walls. Alternatively the interruptions of separate walls may be offset in relation to each other. Thereby the fins formed between the interruptions may not
15 be arranged in rows.

The objects are also achieved by a heat exchanger according to claim 2. Thus, a further aspect of the invention provides a heat exchanger comprising at least one fluid inlet, at least one fluid outlet, a bottom portion, and a top portion, characterized in
20 that the heat exchanger comprises a plurality of rows of fins, the fins being arranged between the bottom portion and the top portion such that a plurality of passages are formed between the bottom portion, the top portion and pairs of adjacent fins, and a plurality of cavities are formed between the bottom portion, the top portion and pairs of adjacent rows of fins, for guiding a fluid from the fluid inlet to the fluid outlet along the
25 passages and at least partly transversely to the cavities.

Each cavity preferably has a main extension along the bottom portion. Guiding the fluid transversely to a cavity means that the fluid is guided transversely to the cavity main extension and along the bottom portion. Guiding the fluid at least partly transversely to the
30 cavity means that the fluid is guided in a direction which has at least a component which is transverse to the cavity main extension.

The bottom portion and at least a portion of the fins may be integrated to form a topological member. Alternatively the bottom portion and the fins may be formed by
35 separate parts. The passages formed between the bottom portion, the top portion and

pairs of adjacent fins may be formed by depressions formed by the pairs of adjacent fins and the bottom portion, whereby the passages are formed by the depressions and the top portion. The passages may be formed regardless whether the bottom portion and the fins are integrated or formed as separate parts. Where the heat exchanger comprises a
5 topological member, the latter may be provided with a surface presenting the plurality of rows of fins, whereby pairs of adjacent fins form a respective depression between them, which as suggested may provide with the top portion a respective of the passages.

As suggested, the fins may be formed by walls arranged between the bottom portion and
10 the top portion such that a plurality of channels are formed between the bottom portion, the top portion and pairs of adjacent walls. As also suggested, the walls may present interruptions, each interruption fluidly connecting two adjacent channels to each other. Thus, said passages between the fins, the bottom portion and the top portion may form portions of said channels, each channel portion extending across one of the rows of fins.

15

In some embodiments, the locations and/or distribution of fins along the rows may differ from one row to another. In addition or alternatively, the angles of the fins in relation to the extension of the respective rows may differ from one row to another.

20 The top portion is herein also referred to as a closing member. The top portion may be fixed to the bottom portion and the fins so as for the rows of fins to form with the closing member separation sections separated by cavities for guiding the fluid from the fluid inlet to the fluid outlet, between the bottom portion and the top portion, along the passages and at least partly transversely to the cavities.

25

The further aspect of the invention provides a heat exchanger, or a cooler, wherein the fluid may be a cooling fluid, e.g. oil or water. E.g. where the bottom portion and the fins are integrated to form a topological member, each row of fins may be formed by a ridge presenting a plurality of the depressions and each cavity may be formed by the top portion
30 and a groove between two of the ridges so that each depression extends from a groove on one side of the respective ridge to a groove on the opposite side of the respective ridge. The depressions could be slots extending transversely in the respective ridge. Thus, the depressions may be presented by the ridges forming rows of fins. Again, the passages may be formed in the heat exchanger by the depressions and the top portion.

35

In some embodiments, at least one of the passages, preferably all of them, in at least one of the rows of fins presents a passage depth extension oriented perpendicularly to the intended flow direction of the fluid in the passage and perpendicularly to a main extension of the row of fins, the depth extension being smaller than the extension in the same
5 direction of the cavities adjacent to the at least one of the passages. Thereby, where each row of fins is formed by a ridge presenting a plurality of the depressions and each cavity is formed by the top portion and a groove between two of the ridges, at least one of the depressions, preferably all of them, is shallower than at least one, preferably all, of the grooves. The depth of the depressions may be 50-95%, for example around 80%, of the
10 depths of the grooves. This provides an additional stimulation of the beneficial turbulence of the fluid, e.g. oil, described below. Alternatively, the depressions and the grooves may present the same depth.

In each row the plurality of the fins may be arranged to guide parallel flows of the fluid.
15 The cavities and the passages may provide a plurality of passageways for guiding a fluid from the fluid inlet to the fluid outlet, between the top portion and the bottom portion, along the passages and transversely to the cavities. Each cavity may be arranged to merge the flows of the fluid exiting the plurality of passages of a row of fins. The cavities may therefore be referred to as merging sections. Thereby the passageways may be arranged
20 in a plurality of alternating separation sections and merging sections.

Aspects of the invention are particularly advantageous where the fluid is oil, e.g. where the oil provides a double function of cooling and lubricating, as exemplified below. As suggested, oil flows are not inherently turbulent at low flow rates, and the lack of
25 turbulence may impede an effective heat transfer from the oil. As the oil exits the passages of a separation section the cavities make the oil flow turbulent. More specifically, upon exit from the passages, the oil will tend to flow in spirals since the oil is forced to slow down. The resulting turbulence will considerably improve the heat transfer from the oil.

30

In addition, the rows of fins may provide a very high wet area, further facilitating the heat transfer in the heat exchanger. Also, the heat exchanger according to the further aspect of the invention may combine relative large heat transferring areas with small flow losses due to the arrangement of the fins and cavities. Also, the turbulence will facilitate heat
35 transfer in a lateral direction in relation to the local direction of the fluid flow.

Further, the fins may provide a double function of guiding the cooling flow and provide supports for the closing member against the topological member. In addition, as explained further below, aspects of the invention may provide for a particularly simple manufacturing
5 process of the heat exchanger.

Said beneficial turbulence may be stimulated as follows: An area of a cross-section of at least one of the cavities, which cross-section is oriented perpendicularly to the intended flow direction of the fluid in the cavity, may be larger than the sum of the areas of cross-
10 sections of the passages of the row of fins immediately preceding the cavity along the intended flow direction of the fluid, which passage cross-sections are oriented along the row of fins and perpendicularly to the intended flow direction of the fluid in the passages. In the case of the fluid being oil, upon exit from the passages, due to the enlarged cross-flow area, the oil will tend to flow in spirals since the oil is forced to slow down. An
15 alternating arrangement of separation sections and the cavities along the fluid path will provide for this beneficial turbulence trigger to appear repetitively as the oil moves from the fluid inlet to the fluid outlet.

Advantageously, a ratio of said area of said cross-section of the cavity and said sum of
20 the areas of the cross-sections of the passages of the row of fins is at least 1.5, preferably at least 2. It is understood that said cavity cross-section is oriented perpendicularly to an imaginary line representing the shortest distance from the row of fins immediately preceding the cavity along the fluid path to the row of fins immediately following the cavity along the fluid path.

25

Preferably, each fin is oriented perpendicularly to the direction of the respective row. Thereby, the passages formed by the bottom portion, the top portion and adjacent fins will extend a minimal distance from one side of the respective row to the other one. However, in some embodiments, as exemplified below, the each fin may be oriented in an angle
30 larger than zero degrees and less than 90 degrees to the direction of the respective row.

The invention is advantageously preferably applied where the bottom portion or the top portion presents a cylindrical surface, e.g. an inner surface of the topological member, and the rows of fins and the cavities are arranged to guide the fluid in a circumferential
35 direction in relation to the cylindrical surface. In alternative embodiment, the separation

sections and the cavities may be arranged to guide the fluid in an axial direction in relation to the cylindrical surface, or in a direction which has an axial as well as a circumferential component. In further alternative embodiments, the topological member and the closing member may provide a planar fluid path.

5

Preferably, where the bottom portion or the top portion presents a cylindrical surface, the rows of fins and the cavities extend in an axial direction in relation to the cylindrical surface. Each fin or each wall may extend mainly in a radial and a circumferential direction in relation to the cylindrical surface. Thereby pairs of adjacent fins may each
10 form with the bottom portion and the top portion respective passages for a flow of the fluid in a circumferential direction in relation to said cylindrical surface. In other words, the walls forming the fins may be arranged to guide the fluid in a circumferential direction in relation to the cylindrical surface.

15 In alternative embodiments, the rows of fins and the cavities extending so as to present a spiral form along the cylindrical surface. Thereby, rows and cavities will extend with an axial as well as a circumferential component. Although the cavities extend in a spiral shape along the cylindrical surface, each fin or each wall may extend mainly in a radial and a circumferential direction in relation to the cylindrical surface. In such embodiments,
20 the fluid may be guided in the circumferential direction of the cylindrical surface, along the passages and partly transversely to the cavities, i.e. in an angle to the cavities so that the general fluid guiding direction presents a component which is transverse to the cavities, and a component which extends along the cavities. In some embodiments, pairs of adjacent fins may form with the bottom portion and the top portion respective passages
25 for a flow of the fluid in a direction which is partially circumferential and partially axial in relation to said cylindrical surface.

In advantageous embodiments, the bottom portion and the top portion form parts of a body of the heat exchanger, the heat exchanger further comprising at least one further
30 fluid inlet, at least one further fluid outlet, and at least one further passage arranged in the body to guide a further fluid from the further fluid inlet to the further fluid outlet. The further fluid could advantageously be water arranged to exchange heat with the fluid guided between the topological member and the closing member.

Where the bottom portion or the top portion presents a cylindrical surface, the further passage may be arranged to guide the further fluid in an axial direction in relation to the cylindrical surface. Thereby, where the topological member and the closing member are arranged to guide the fluid in a circumferential direction, the axial direction of the further fluid may stimulate an effective heat transfer between the fluids. For example, embodiments may provide for oil to flow in the circumferential direction and water to flow in the axial direction. Combined with the beneficial turbulence triggering effect of the oil described above, a particularly effective absorption by the water of heat from the oil may be provided.

10

In alternative embodiments, the further passage is arranged to guide the further fluid in a direction with an axial component and a circumferential component in relation to the cylindrical surface. In such embodiments, the further passage extend with a spiral shape along the cylindrical surface.

15

The heat exchanger may advantageously comprise a plurality of further passages arranged in the body to guide the further fluid from the further fluid inlet to the further fluid outlet. Thereby, an end cavity may be provided in an axial end region of the body, the end cavity extending circumferentially in relation to the cylindrical surface so as to communicate with at least two of the further passages. The further fluid inlet may thereby be arranged to introduce the further fluid into the end cavity in a direction with a component in the circumferential direction of the body. This will provide a beneficial distribution of the water delivered by the further fluid inlet in the circumferential direction of the end cavity. The direction with the component in the circumferential direction is understood as a direction which, as projected in an imaginary plane which is perpendicular to the axial direction of the body, presents a non-zero angle to a radial direction of the body. This further fluid inlet arrangement provides an improved fluid flow pattern in the heat exchanger.

30 In some embodiments, where the bottom portion or the top portion presents a cylindrical surface, the further passage may be arranged to guide the further fluid in a circumferential direction in relation to the cylindrical surface. Thereby, where the bottom portion and the top portion are arranged to guide the fluid in a circumferential direction, an advantageous counter flow of the further fluid will be achieved. This is particularly beneficial if the temperature difference between the fluids is low, or if the flows are low.

35

In preferred embodiments, where the bottom portion or the top portion presents a cylindrical surface, the at least one further passage is entirely located radially inside the walls or the fins. Such embodiments are particularly advantageous where the heat
5 exchanger body encloses a heat source such as an electric motor, and where the fluid between the topological member and the closing member form a part of a cooling circuit with a passageway through a further heat source, such as a transmission. The fluid of the cooling circuit may thereby be oil, and the further passage may be arranged to guide water. The water may then have the double function of cooling oil as well as the other
10 heat source, e.g. in the form of a motor. Such a layered arrangement will provide a highly beneficial heat exchange.

Preferably, where the bottom portion or the top portion presents a cylindrical surface, the top portion forms an outer member, and the bottom portion forms a part of an intermediate
15 member located concentrically with and radially inside the outer member, the body further comprising an inner member located concentrically with and radially inside the intermediate member. Thus, said grooves and depressions may be formed on an outer surface of the intermediate member which is beneficial from a manufacturing point of view. Preferably, sealing elements are provided between the intermediate member and
20 the outer member, which sealing elements extend circumferentially around the intermediate member, the sealing elements being located on opposite axial sides of the passageways which are distributed along the fluid path between the intermediate member and the outer member.

25 The at least one further passage may be provided as a plurality of further passages, and the further passages may be formed on an outer surface of the inner member and/or an inner surface of the intermediate member by a plurality of inner ridges separated by inner grooves. Thereby, a wet surface provided by a plurality of the inner ridges on the inner surface of the intermediate member and a wet surface provided by a plurality of the inner
30 ridges on the outer surface of the inner member may be mutually adapted to a desired relationship between a heat transport from the fluid guided by the passageways between the intermediate member and the outer member to the further fluid and a heat transport from a heat source located radially inside the inner member to the further fluid. Thereby, the heat transfer from two heat sources may be carefully balanced, e.g. by a suitable

selection of the relationship of the heights of the inner ridges of the intermediate member and the inner ridges of the inner member.

The inner ridges on said members may present the same widths. The inner ridges on said
5 members may be axially aligned. Thereby, as exemplified below, adjacent pairs of a
respective inner ridge on the intermediate member and a respective inner ridge on the
inner member may form the further passages between them.

The objects are also reached with a motor and transmission combination with a
10 transmission cooling circuit, characterized in that the combination comprises a heat
exchanger according to any one of claims 13-22, wherein the transmission cooling circuit
is arranged to communicate with the fluid inlet and the fluid outlet, wherein the body
encloses the motor, the at least one further passage being entirely located radially inside
the walls or the fins. As mentioned above, the working fluid of the transmission cooling
15 circuit could be oil. The motor and transmission combination may provide an
advantageous solution for transferring heat from the oil to the further fluid, e.g. in the form
of water.

The invention is advantageously applied to a working machine. In particular, a working
20 machine may comprise a combination according to claim 23 at at least one wheel hub of
the working machine for propulsion of the working machine.

The objects are also reached with a heat exchanger comprising a first member with a
surface presenting a plurality of ridges separated by grooves, and a second member
25 positioned adjacent the first member whereby the heat exchanger is arranged to guide a
cooling fluid between the first and second members, the second member presenting on a
surface facing said surface of the first member a plurality of ridges separated by grooves.
It is understood that the heat exchanger may be arranged to guide the cooling fluid
between the first and second members from a fluid inlet to a fluid outlet.

30

Such a heat exchanger provides for a wet surface provided by the ridges of the first
member and a wet surface provided by the ridges of the second member to be mutually
adapted to a desired relationship between a heat transport from a first element, located on
a side of the first member which is opposite to the side on which the second member is
35 located, to the cooling fluid, and a heat transport from a second element, located on a

side of the second member which is opposite to the side on which the first member is located, to the cooling fluid. As also suggested above, thereby, the heat transfer from the first and second elements may be carefully balanced, e.g. by a suitable selection of the relationship of the heights of the ridges of the first member and the ridges of the second member.

Advantageously, the first and second member are cylindrical and the second member is positioned coaxially to the first member and radially inside the first member. Thereby, similarly to what has been described above, the ridges of the first and second members may extend circumferentially.

The object are also reached with a method for manufacturing a heat exchanger, characterized by the steps of providing a topological member with a surface presenting a plurality of ridges separated by grooves, providing a plurality of depressions in each of a plurality of the ridges so that each depression extends from a groove on one side of the respective ridge to a groove on the opposite side of the respective ridge, positioning a closing member in relation to the topological member so as for the grooves and the depressions to provide passageways for a cooling fluid between the topological member and the closing member.

20

Thereby, a very simple and cost effective manufacturing process of the advantageous heat exchanger described above is provided. The depressions may be provided subsequently to the provision of the topological member with the surface presenting the plurality of ridges separated by grooves. The topological member may be provided by extrusion. Extrusion is known as a process used to create objects of a fixed cross-sectional profile, in which process a material, e.g. aluminum, is pushed through a die of the desired cross-section. Extrusion can be very cost effective. The method facilitating the use of this cost effective process, and also allows the ridges with the depressions to provide the beneficial heat transfer as well as a relative positioning of the topological member and the closing member, makes the method highly beneficial as a heat exchanger manufacturing process.

The method may be used to provide beneficial embodiments described above. Thus, advantageously, the topological member and the closing member are cylindrical, and the closing member is positioned coaxially with the topological member. Preferably, the ridges

extend in the axial direction of the topological member. Alternatively, the ridges extend in a direction with an axial components as well as a circumferential component in relation to the topological member, whereby, the ridges may extend in a spiral manner along the topographical member.

5

Preferably, said surface is an external surface of the topological member, and the closing member is positioned radially outside the topological member. This facilitates the provision of the depressions, which may be provided by machining in the ridges; the machining could involve the use of a lathe, but alternative methods are possible, e.g.

10 milling.

Preferred embodiments of the method comprise providing a complementary member with a surface presenting a plurality of ridges separated by grooves, positioning the complementary member on a side of the topological member which is opposite to a side
15 on which the closing member is positioned, so as for the grooves of the complementary member to provide passages for a further cooling fluid between the complementary member and the topological member. As described above, thereby a beneficial heat transfer between the cooling fluid may be provided.

20 Embodiments of the method may comprise providing on a surface of the topological member, which is opposite to said surface of the topological member presenting a plurality of ridges separated by grooves, a plurality of further ridges separated by further grooves, positioning a complementary member in relation to the topological member so as for the further grooves of the topological member to provide passages for a further cooling
25 fluid between the topological member and the complementary member. Thereby, the method may further comprise determining a relationship between a heat transport from the cooling fluid between the topological member and the closing member to the further cooling fluid and a heat transport from a heat source on a side of the complementary member, which is opposite to the side on which the topological member is provided, to the
30 further cooling fluid, and mutually adapting a wet surface provided by the ridges of the topological member and a wet surface provided by the ridges of the complementary member to said determined heat transport relationship. Thereby, the method may provide a heat exchanger which, as also suggested above, provides for the heat transfer from the heat source and the cooling fluid between the topological member and the closing
35 member to be carefully balanced, e.g. by a suitable selection of the relationship of the

heights of the ridges of the topological member and the ridges of the complementary member.

The method preferably comprises, where the topological member, the closing member
5 and the complementary member are cylindrical, positioning said members mutually concentrically with the closing member radially outside the topological member and the complementary member radially inside the topological member.

The objects are also reached with a method for manufacturing a heat exchanger,
10 characterized by the steps of providing by extrusion a cylindrical body with a plurality of axial surface grooves separated by axial ridges, cutting along a radial cross-section the cylindrical body into a plurality of ridged members, positioning a cylindrical covering member coaxially with a respective of the ridged members so as for the axial surface grooves to provide passages for a cooling fluid between the ridged member and the
15 covering member. Thereby, the cost effective process of extrusion can be used to manufacture a heat exchanger where the ridges provide a double function of guiding a cooling fluid and positioning by abutment the cylindrical covering member in relation to the ridged member.

20 The surface grooves and the ridges of the cylindrical body may be axial. Alternatively, the surface grooves and the ridges of the cylindrical body may extend in a direction with an axial component and a circumferential component.

The method preferably comprises machining by the use of a lathe a plurality of
25 circumferentially oriented depressions in each of a plurality of the axial ridges. Thereby, a simple manner is provided of manufacturing a heat exchanger which provides the turbulence triggering described above as highly beneficial in particular where the cooling fluid is oil.

30 Embodiments of the method may comprise removing, at an axial end portion of the respective ridged member, material from at least one of the ridges, so as for the ridged member and the covering member to provide an end cavity extending circumferentially past the at least one ridge from which material was removed. As exemplified below, a beneficial distribution of the cooling fluid to the passages may thereby be provided.

The objects are also reached with a method for providing a heat exchanger comprising providing a first member with a surface presenting a plurality of ridges separated by grooves, characterized by providing a second member with a surface presenting a plurality of ridges separated by grooves, positioning the second member adjacent the first member so that said surface of the second member faces said surface of the first member, so as for the ridges to form passages for a cooling fluid between the first and second members. Thereby, the method may comprise determining a relationship between a heat transport from a first element, located on a side of the first member which is opposite to the side on which the second member is located, to the cooling fluid, and a heat transport from a second element, located on a side of the second member which is opposite to the side on which the first member is located, to the cooling fluid, and mutually adapting a wet surface provided by the ridges of the first and second members to said determined heat transport relationship. Thereby, the method may provide a heat exchanger which, as also suggested above, provides for the heat transfer from the first and second elements to be carefully balanced.

Further advantages and advantageous features of the invention are disclosed in the following description and in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a more detailed description of embodiments of the invention cited as examples.

In the drawings:

Fig. 1 is a side view of a working machine in the form of a wheel loader.

Fig. 2 is a side view of the wheel loader in fig. 1, showing parts in the wheel loader.

Fig. 3 shows an axially oriented cross-section of a hub of the wheel loader in fig. 1.

Fig. 4 shows a cross-section of a heat exchanger in the hub in fig. 3, the cross-section being oriented as indicated by the arrows IV-IV in fig. 3.

Fig. 5 shows a perspective view of a portion of a part of the heat exchanger in fig. 4.

Fig. 6 shows a perspective view of another part of the heat exchanger in fig. 4.

- 5 Fig. 7 shows an axially oriented cross-section of a portion of a heat exchanger according to an alternative embodiment of the invention.

Fig. 8 – fig. 10 show respective perspective views of work pieces provided as respective results of steps in a method of manufacturing the heat exchanger in fig. 4.

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Fig. 11 is a diagram depicting the steps in the method of manufacturing the heat exchanger in fig. 4.

Fig. 12 is a diagram depicting steps in a method of providing the heat exchanger partly

15 shown in fig. 7.

Fig. 13 shows a perspective view of a part corresponding to the part in fig. 6, according to an alternative embodiment of the invention.

- 20 Fig. 14 shows a perspective view of a portion of a part corresponding to the part in fig. 5, according to yet another embodiment of the invention.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

- 25 Fig. 1 is an illustration of a working machine 1 in the form of a wheel loader. The wheel loader is an example of a working machine where a heat exchanger according to a suitable embodiment of the invention can be applied.

The wheel loader 1 has an implement 2. The term “implement” is intended to comprise
30 any kind of tool controlled by hydraulics, such as a bucket, a fork or a gripping tool. The implement 2 illustrated in fig. 1 is a bucket 3 which is arranged on a load arm 4 for lifting and lowering the bucket 3. Further the bucket can be tilted relative to the load arm. In the example illustrated in fig. 1, a hydraulic system of the wheel loader 1 comprises two hydraulic cylinders 5, 6 for the operation of the load arm 4 and one hydraulic cylinder 7 for
35 tilting the bucket 3 relative to the load arm.

The hydraulic system of the wheel loader further comprises two hydraulic cylinders 8, 9, steering cylinders, arranged on opposite sides of the wheel loader 1 for turning the wheel loader by means of relative movement of a front body part 10 and a rear body part 11. In other words: The wheel loader 1 is articulated and frame steered by means of the steering cylinders 8, 9. There is a pivot joint connecting the front body part 10 and the rear body part 11 of the wheel loader 1 such that these parts are pivotally connected to each other for pivoting about a substantially vertical axis.

Reference is made to fig. 2. The wheel loader 1 has an electric hybrid propulsion system. More specifically, the propulsion system is provided in a series electric hybrid configuration. An internal combustion engine 101 is connected to a generator 102, in turn connected to an electric storage arrangement in the form of a battery pack (not shown). The wheel loader 1 is provided with four wheels 12, i.e. two on each body part 10, 11. At each wheel 12 a torque control assembly 13 is provided. The torque control assemblies 13 are located in the hubs of the respective wheels 12.

It should be noted that the invention is applicable to working machines with other types of propulsion systems, e.g. fully electric propulsion systems. It should further be noted that in alternative applications, e.g. with hybrid propulsion systems, the working machine may be provided without any electric storage arrangement.

As understood from fig. 3, each torque control assembly 13 comprises a motor and transmission combination 131, 132 with a transmission cooling circuit, an electric propulsion motor 131 for transferring torque to the respective wheel 12 via a gear assembly 132. The electric motors are powered by the battery pack, and controlled by a control unit 14, (fig. 2). In addition to powering the electric motors 13, the battery pack is used for powering various devices in the wheel loader 1, such as one or more hydraulic pumps for powering the hydraulic cylinders 5, 6, 7 for the load arm 4 and the bucket tilting, and also the steering cylinders 8, 9, (fig. 1). Each torque control assembly 13 comprises in addition a brake assembly 161 of a vehicle brake system.

The motor and transmission combination 131, 132 further comprises a transmission cooling circuit 133. The transmission cooling circuit is arranged to cool and lubricate the transmission 132 and the brake assembly 161. The working fluid of the transmission

cooling circuit 133, herein also referred to as a cooling fluid, is oil. The motor and transmission combination 131, 132 also comprises a heat exchanger 91 described further below. The transmission cooling circuit 133 is arranged to communicate via a pump 134 with a fluid inlet 902 and a fluid outlet 903 of the heat exchanger 91 as described below.

- 5 The heat exchanger comprises a body 901 enclosing the motor 131. Even if only one fluid inlet 902 and one fluid outlet 903 are shown in fig. 3 it is understood that the transmission cooling circuit 133 may present more than one fluid inlet 902 and more than one fluid outlet 903.
- 10 Fig. 4 shows a cross-section of the heat exchanger 91. The heat exchanger 91 comprises in addition to the fluid inlet 902 and the fluid outlet 903 described further below, a body 901, in turn comprising an outer member 912, herein also referred to as a closing member 912 or a top portion 912, an intermediate member 911, herein also referred to as a topological member 911, and an inner member 913. The intermediate member 911
- 15 comprises what is herein referred to as a bottom portion 9112.

The body 91 is substantially cylindrical. The intermediate member 911 presents a cylindrical inner surface 941. The outer member 912 presents a cylindrical inner surface 942. The inner member 913 presents a cylindrical inner surface 943. As understood from

20 the description below, the members 911, 912, 913 may present other cylindrical surfaces. Also, said inner surfaces 941, 942, 943 may be smooth or present a topology as exemplified below. In the latter case, the inner surfaces 941, 942, 943 may nevertheless have a generally cylindrical shape.

- 25 The intermediate member 911 is fixed to the outer member 912, and is located concentrically with and radially inside the outer member 912. The inner member 913 is fixed to the intermediate member 911, and located concentrically with and radially inside the intermediate member 911.

- 30 The intermediate member 911 presents on its outer surface a plurality of ridges 907 separated by grooves 9061, and a plurality of depressions 908, described closer below. The ridges 907 and the grooves 9061 extend in the axial direction in relation to the cylindrical inner surface 941 of the intermediate member 911.

The heat exchanger further comprises a further fluid inlet 921, a further fluid outlet, and a plurality of further passage 923 arranged in the body 901 to guide a further cooling fluid from the further fluid inlet 921 to the further fluid outlet. The further cooling fluid is water with a suitable antifreeze additive. The further fluid inlet 921 and the further fluid outlet are
5 located at opposite axial ends of the body 901.

The further passage 923 are arranged to guide the water in an axial direction in relation to the inner surface 941 of the intermediate member 911. The further passages 923 are located radially inside the intermediate member 911. The further passages 923 are
10 formed on an outer surface of the inner member 913 by a plurality of further ridges 932, herein also referred to as inner ridges, separated by further grooves 9231, herein also referred to as inner grooves. Thus, the further passages 923 are formed by the further grooves 9231 and the inner surface of the intermediate member 911.

15 The further ridges 932 abut against the inner surface of the intermediate member 911. Thereby, the further ridges 932 serve the double function of distributing the water in the further passages 923 and positioning the inner member 913 concentrically with the intermediate member 911.

20 As suggested in fig. 5, the intermediate member 911 presents at each axial end a circumferential slot 9111 for a sealing element in the form of an O-ring (not shown). Thus, at each axial end of the intermediate member 911, such a sealing element is provided between the intermediate member 911 and the outer member 912, which sealing elements extend circumferentially around the intermediate member 911.

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As can be seen in fig. 5, the depressions 908 presented on the outer surface of the intermediate member 911 are formed in each of a plurality of the ridges 907 of the intermediate member 911 so that each depression 908 extends from a groove 9061 on one side of the respective ridge 907 to a groove 9061 on the opposite side of the
30 respective ridge 907. The depressions 908 are shaped as slots extending transversely in the respective ridge 907. Thereby, each ridge 907 forms a plurality of fins 9081, whereby pairs of adjacent fins 9081 form a respective of the depressions 908 between them. Thus, the fins 9081 of each ridge 907 form a row 9071 of fins 9081 extending in an axial direction in relation to the cylindrical inner surface 941 of the intermediate member 911. It
35 is understood that each fin 9081 extends mainly in a radial and a circumferential direction.

The intermediate member 911 comprises the bottom portion 9112 and the fins 9081. The bottom portion 9112 and the fins 9081 are in this embodiment integrated with each other. The fins are formed by walls 9082 which are thus arranged between the bottom portion
5 9112 and the top portion 912, (the outer member 912, fig. 4), such that a plurality of channels 9083 are formed between the bottom portion 9112, the top portion 912 and pairs of adjacent walls 9082. The walls 9082 present interruptions 9062, each interruption 9062 fluidly connecting two adjacent channels 9083 to each other. Portions of said channels 9083 extending between grooves 9061 on opposite sides of the respective ridge 907 form
10 passages 9084. The interruptions 9062 are aligned to form said grooves 9061.

As understood from fig. 4, the outer member 912 provides with the grooves 9061 and the depressions 908 a plurality of passageways 906, 9084 for guiding the oil from the fluid inlet 902 to the fluid outlet 903, between the intermediate member 911 and the outer
15 member 912, along the depressions 908 (fig. 5) and transversely to the grooves 9061. In particular, each depression 908 forms with the outer member 912 a respective of the passages 9084. Although locations of the passages 9084 are suggested in fig. 5 not showing the outer member 912, it is understood that the passages 9084 are formed by the depressions 908 and the outer member 912 shown in fig. 4. Thus, in each ridge 907
20 the plurality of the depressions 908 are arranged to guide parallel flows of the oil.

As can be seen in fig. 4, the fluid inlet 902 and the fluid outlet 903 for the oil are located on opposite sides of the body 901, i.e. the fluid inlet 902 and the fluid outlet 903 are located so as to be separated circumferentially by 180 degrees. Thereby, the outer
25 member 912 and the intermediate member 911 form two fluid paths P. The fluid paths P extend in the circumferential direction of the body 901. The fluid paths P are symmetrical each extending along approximately 180 degrees of the body 901 circumference.

It should be noted that in alternative embodiments, there could be a single fluid path P
30 extending around the entire body 901; thereby, the fluid inlet 902 and the fluid outlet 903 may be in the vicinity of each other, and an axial bulkhead could prevent any flow directly from the inlet 902 to the outlet 903. I.e. the bulkhead may force the oil around the entire body 901.

- The fluid paths P are at the ridges 907 of the intermediate member 911 divided into the plurality of parallel flows provided by the depressions 908. Each groove 9061 forms with the outer member 912 a cavity 906. Each ridge 907 forms with the depressions 908 and the outer member 912 what is herein referred to as a separation section 905. The
- 5 separation sections 905 and the cavities 906 are arranged alternately along the fluid path P. Each cavity 906 is arranged to merge the flows of the oil exiting the plurality of depressions 908 of the respective ridge 907 located immediately before the respective cavity 908 in the direction of the respective fluid path P.
- 10 Herein a cross-flow cavity cross-section is defined as a cross-section which is oriented along the groove 9061 and perpendicularly to the intended flow direction, i.e. the local fluid path P direction, of the oil in the cavity 906. Also, a cross-flow depression cross-section is defined as a cross-section which is oriented along the respective ridge 907 and perpendicularly to the local fluid path P direction. The area of the cross-flow cavity cross-
- 15 section of each cavity 906 is larger than the sum of the areas of cross-flow depression cross-sections of the depressions 908 of the ridge 907 immediately preceding the cavity 906 along the fluid path P. This provides as discussed above a highly advantageous turbulence of the oil, giving a high heat transfer capacity of the heat exchanger.
- 20 Fig. 6 shows the outer surface of the inner member 913 with the plurality of further ridges 932 separated by the further grooves 9231. The arrow A indicates the direction of the water in one of the further passages 923.
- Two cylindrical surfaces 9241, 9251 are provided in respective opposite axial end regions
- 25 of the inner member 913. The cylindrical surfaces 9241, 9251 of the end regions are located radially inside the radial limitations of the further ridges 932. Thus, the cylindrical surfaces 9241, 9251 form with the intermediate member 911 (fig. 4) respective end cavities 924, 925 in respective opposite axial end regions of the body 901 (fig. 4).
- 30 The end cavities 924, 925 extend circumferentially so as to communicate with the further passages 923. As understood from fig. 4 and fig. 6, the further fluid inlet 921 is arranged to introduce the water into one of the end cavities 924 in a direction with a component in the circumferential direction of the body 901. This will provide a beneficial distribution of the water delivered by the further fluid inlet 921 in the circumferential direction of the end
- 35 cavity 914.

Fig. 7 shows a cross-section of a portion of a heat exchanger according to an alternative embodiment of the invention. The heat exchanger shares many features with the embodiment described above with reference to fig. 3 – fig. 6. Thus, the heat exchanger
5 has a generally cylindrical body 901 as well as a fluid inlet and a fluid outlet located on opposite sides of the body. The cross-section in fig. 7 is oriented in the axial direction of the body 901, and shows a portion of the cylindrical “wall” of the body.

Similarly to the embodiment described above with reference to fig. 3 – fig. 6, the body
10 comprises an outer member 912 an intermediate member 911 and an inner member 913. Also, similarly to the embodiment described above with reference to fig. 3 – fig. 6, the intermediate member 911 has an outer surface presenting a plurality of rows of fins 9081, which form with the outer member 912 separation sections 905 separated by cavities for guiding oil from the fluid inlet 902 to the fluid outlet 903 along depressions 908 formed by
15 the fins 9081 and transversely to the cavities. In particular, each depression 908 forms with the outer member 912 a passage 9084. Similarly to what is shown in fig. 4, the outer member 912 and the intermediate member 911 form two fluid paths P extending in the circumferential direction of the body 901.

20 Differing from the embodiment describe above with reference to fig. 3 – fig. 6, the further passages 923 between the intermediate member 911 and the inner member 913 are arranged to guide the water in a circumferential direction of the body 901. Thereby, the further fluid inlet and the further fluid outlet for the water are on opposite sides of the body, separated circumferentially by 180 degrees, similarly to the fluid inlet 902 and the fluid
25 outlet 903 for the oil shown in fig. 4. Thereby, the inner member 913 and the intermediate member 911 form two fluid paths extending in the circumferential direction of the body 901.

As can be seen in fig. 7, the a plurality of further ridges 931 are provided on the inner
30 surface of the intermediate member 911, and a plurality of further ridges 932 are provided on the outer surface of the inner member 913. The further ridges 931, 932 extend continuously along the circumferential direction of the inner and intermediate members 913, 911.

The further ridges 931, 932 on the inner and intermediate members 913, 911 are located at matching axial positions, whereby each further ridge 931 on the intermediate member 911 form a pair with a respective of the further ridges 932 on the inner member 913. The further ridges 931, 932 in each such pair about each other at the distal ends of the further
5 ridges 931, 932. Thereby, each of the further passages 923 are formed between two of said pairs of the further ridges 931, 932.

The heights of the further ridges 931, 932 are adapted in the following manner: The wet surface provided by the further ridges 931 on the intermediate member 911 and the wet
10 surface provided by the further ridges 932 on the inner member 913 are mutually adapted to a desired relationship between a heat transport from the oil guided by the passageways 906, 9084 between the intermediate member 911 and the outer member 912 to the water and a heat transport from the motor 131 (fig. 3) located radially inside the inner member 913 to the water. In the example in fig. 7, the wet surface provided by the further ridges
15 931 on the intermediate member 911 is larger than the wet surface provided by the further ridges 932 on the inner member 913. This means that there will be a larger heat transport capacity from the oil between the outer member 912 and the intermediate member 911 to the water between the inner member 913 and the intermediate member 911, than from the motor to the water between the inner member 913 and the intermediate member 911.

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It should be noted that the wet surface adaption of the further ridges 931, 932 may be used wherever there is a need to balance the heat transfer between two heat sources on either side on the further passages 923. Thus, said wet surface adaption is useful also in applications where the water is the only liquid in a cooling system, and the oil in the
25 embodiment described with reference to fig. 7 is replaced by any heat source being located on the opposite side of the passages 923 in relation to the heat source formed by the motor 131. Also, said wet surface adaption is useful also in applications where the motor is replaced by a third fluid transported on the side of the inner member which is opposite to the side on which the further passages 923 are provided. Again it should
30 further be noted that the body of the heat exchanger may have a shape that is not cylindrical, e.g. it could be planar.

With reference to fig. 8 – fig. 11, a method of manufacturing the heat exchanger described above with reference to fig. 3 – fig. 6 will be described.

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The method comprises for providing the intermediate member 911, herein also referred to as the topological member 911, extruding S1 a first cylindrical body 911A with a generally circular cross-section, e.g. in aluminum. The first cylindrical body 911A has an external surface with a plurality of ridges 907 separated by grooves 9061. The ridges 907 extend
5 in the axial direction of the work piece 911A.

As understood from fig. 9, the first cylindrical body 911A is cut S2 orthogonally to its axial direction into a plurality of first ridged members 911B.

- 10 Reference is made to fig. 10. By machining S3, e.g. by the use of a lathe, a plurality of depressions 908 are provided in each of the ridges 907 so that each depression 908 extends from a groove 9061 on one side of the respective ridge 907 to a groove 9061 on the opposite side of the respective ridge 907.
- 15 Also, at each axial end of the first ridged member 911B, a circumferential slot 9111 is provided for a respective of the sealing elements described above with reference to fig. 5. Thereby, the intermediate member 911 (fig. 4) is provided.

The method further comprises providing the inner member 913, herein also referred to as
20 a complementary member 913, by extrusion S4, e.g. in aluminum, to provide a second cylindrical body with axial external further ridges, similarly to the first cylindrical body 911A in fig. 8. The second cylindrical body is then cut S5 perpendicularly to the axial direction into a plurality of second ridged members, each similar to the first ridged member 911B in fig. 9.

25 Subsequently, at both axial end portions of the respective second ridged members, material is removed from the further ridges, so as for each second ridged member to be provided two cylindrical surfaces 9241, 9251, as described above with reference to fig. 6. Thereby, the inner member 913 (fig. 4) is provided.

30 Subsequently, an outer member 912 with a tubular shape is positioned coaxially in relation to the intermediate member 911, and fixed to the intermediate member 911, so as for the grooves 9061 and the depressions 908 to provide the passageways 906, 9084 described above with reference to fig. 3 – fig. 6. Also, the inner member 913 is positioned
35 coaxially in relation to the intermediate member 911, and fixed to the intermediate

member 911, so as for the further grooves 9231 to provide the further passages 923 described above with reference to fig. 3 – fig. 6, and so as for the cylindrical surfaces 9241, 9251 to form with the intermediate member 911 the respective end cavities 924, 925.

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With reference to fig. 12, a method of providing the heat exchanger described above with reference to fig. 7 will be described.

In a design step, a desired relationship between a heat transport from the oil between the intermediate member 911 and the outer member 912 to the water, and a heat transport from the motor 131 (fig. 3) to the water, is determined. Based on this determination, the height of the further ridges 931 (fig. 7) on the inner surface of the intermediate member 911, and the height of the further ridges 932 on the outer surface of the inner member 913, are determined S9. This provides a mutual adaption of the wet surface provided by the further ridges 931 of the intermediate member 911 and the wet surface provided by the further ridges 932 of the inner member 913 to said determined heat transport relationship.

The intermediate member 911 in fig. 7 is manufactured S10 in a manner similar to what was described above with reference to fig. 8 – fig. 11. In addition to providing the grooves 9061 and the depressions 908 on the outer surface of the intermediate member 911, the further ridges 931 (fig. 7) are provided by creating circumferential grooves in the inner surface of the intermediate member 911 by the use of a lathe.

The inner member 913 is manufactured S11 by creating on the outer surface of a tubular, cylindrical work piece a plurality of circumferential grooves by the use of a lathe to provide the circumferential further ridges of the inner member 913. The outer member 912 is provided as a cylindrical tube. The outer, intermediate and inner members are positioned coaxially in relation to each other, and fixed to each other so as to produce the body of the heat exchanger described with reference to fig. 7.

Fig. 13 shows an alternative version of the inner member 913 shown in fig. 6. The inner member shown in fig. 13 shares features with the inner member 913 in fig. 6, but differs as follows: While the further ridges 932 and the further grooves 9231 of the inner member 913 in fig. 6 extend in the axial direction of the inner member 913, the further ridges 932

and the further grooves 9231 of the inner member 913 in fig. 13 extend in a direction with an axial component and a circumferential component. Thereby, the further passages 923 are arranged to guide the further cooling fluid in along respective paths with spiral shapes along the inner member 913.

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The inner member 913 in fig. 13 may be manufactured with a process involving extrusion, similarly to what has been described above. Thereby, the spirally shaped further ridges 932 may be provided by a suitable shape of an extrusion tool used in the extrusion process.

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It should be noted that in further embodiments, an intermediate member similar to the one described above with reference to fig. 5, may present rows of fins extending so as to present a spiral form along the cylindrical surface. Thereby, rows and cavities will extend with an axial as well as a circumferential component. A method of manufacturing such an intermediate member may comprise extruding a first cylindrical body as shown in fig. 8, however, where a tool used in the extrusion is arranged so as to provide the plurality of ridges 907 and grooves 9061 with a spiral shape. These ridges and grooves will be similar to the further ridges 932 and the further grooves 9231 of the inner member 913 in fig. 13.

20 Thereafter, the first cylindrical body may be, as described above with reference to fig. 9, and fig. 10, cut orthogonally to its axial direction into a plurality of first ridged members, and by the use of a lathe, a plurality of depressions may be provided in each of the ridges, providing depressions each extending from a groove on one side of the respective ridge to a groove on the opposite side of the respective ridge. As a result, the intermediate member will present rows of fins extending so as to present a spiral form along the intermediate member. It is understood that if the depressions are formed in the circumferential direction of the intermediate member, each fin will be oriented in an angle larger than zero degrees and less than 90 degrees to the direction of the respective row.

30 In fig. 14 a part of an intermediate member, similar to the one described above with reference to fig. 5, is shown. The intermediate member in fig. 14 shares features with the intermediate member in fig. 5, but differs as follows: The depressions 908 are shallower than the grooves 9061. Thereby, the passages 9084 provided by the depressions 908 and the outer member 912 (fig. 4) will present a passage depth extension oriented in the radial direction of the intermediate member, i.e. perpendicularly to the intended flow direction of

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the fluid in the passages 9084 and perpendicularly to a main extension of the respective row of fins, the depth extension being smaller than the extension in the same direction of the cavities 906 adjacent to the passages 9084. For this the depth of the depressions 908 may be 50-95%, for example around 80%, of the depths of the grooves 9061. This
5 provides an additional stimulation of the beneficial turbulence of the cooling fluid, e.g. oil, described above.

It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize
10 that many changes and modifications may be made within the scope of the appended claims.

CLAIMS

1. A heat exchanger comprising at least one fluid inlet (902) and at least one fluid outlet (903), the heat exchanger comprising a bottom portion (9112), a top portion (912), and a plurality of walls (9082), the walls (9082) being arranged between the bottom portion (9112) and the top portion (912) such that a plurality of channels (9083) are formed between the bottom portion (9112), the top portion (912) and pairs of adjacent walls (9082), wherein the channels (9083) are arranged to guide a fluid from the fluid inlet to the fluid outlet, characterized in that the walls (9082) present a plurality of interruptions (9062), each interruption (9062) fluidly connecting two adjacent channels (9083) to each other.
2. A heat exchanger comprising at least one fluid inlet (902), at least one fluid outlet (903), a bottom portion (9112), and a top portion (912), characterized in that the heat exchanger comprises a plurality of rows (9071) of fins (9081), the fins being arranged between the bottom portion (9112) and the top portion (912) such that a plurality of passages (9084) are formed between the bottom portion, the top portion and pairs of adjacent fins, and a plurality of cavities (906) are formed between the bottom portion, the top portion and pairs of adjacent rows of fins, for guiding a fluid from the fluid inlet (902) to the fluid outlet (903) along the passages (9084) and at least partly transversely to the cavities (906).
3. A heat exchanger according to claim 2, characterized in that the bottom portion (9112) and at least a portion of the fins (9081) are integrated to form a topological member (911).
4. A heat exchanger according to any one of claims 2-3, characterized in that at least one of the passages (9084) in at least one of the rows (9071) of fins (9081) presents a passage depth extension oriented perpendicularly to the intended flow direction of the fluid in the passage and perpendicularly to a main extension of the row (9071) of fins (9081), the depth extension being smaller than the extension in the same direction of the cavities (906) adjacent to the at least one of the passages (9084).

5. A heat exchanger according to any one of claims 2-4, characterized in that in each row (9071) the plurality of the fins (9081) are arranged to guide parallel flows of the fluid.
- 5 6. A heat exchanger according to any one of claims 2-5, characterized in that each cavity (906) is arranged to merge the flows of the fluid exiting the plurality of passages (9084) of a row (9071) of fins (9081).
- 10 7. A heat exchanger according to any one of claims 2-6, characterized in an area of a cross-section of at least one of the cavities (906), which cross-section is oriented perpendicularly to the intended flow direction of the fluid in the cavity, is larger than the sum of the areas of cross-sections of the passages (9084) of the row (9071) of fins (9081) immediately preceding the cavity (906) along the intended flow direction of the fluid, which passage cross-sections are oriented along the row
15 (9071) of fins (9081) and perpendicularly to the intended flow direction of the fluid in the passages.
8. A heat exchanger according to claim 7, characterized in that a ratio of said area of said cross-section of the cavity (906) and said sum of the areas of the cross-
20 sections of the passages (9084) of the row (9071) of fins (9081) is at least 1.5.
9. A heat exchanger according to any one of claims 2-8, characterized in that each fin is oriented perpendicularly to the direction of the respective row.
- 25 10. A heat exchanger according to any one of claim 2-9, characterized in that the bottom portion (9112) or the top portion (912) presents a cylindrical surface (941), the rows (9071) of fins (9081) and the cavities (906) extending in an axial direction in relation to the cylindrical surface.
- 30 11. A heat exchanger according to any one of claims 2-10, characterized in that the bottom portion (9112) or the top portion (912) presents a cylindrical surface (941), the rows (9071) of fins (9081) and the cavities (906) extending so as to present a spiral form along the cylindrical surface.

12. A heat exchanger according to any one of the preceding claims, characterized in that the bottom portion (9112) or the top portion (912) presents a cylindrical surface (941), and each fin (9081) or each wall (9082) extends mainly in a radial and a circumferential direction in relation to the cylindrical surface.

5

13. A heat exchanger according to any one of the preceding claims, characterized in that the bottom portion (9112) and the top portion (912) form parts of a body (901) of the heat exchanger, the heat exchanger further comprising at least one further fluid inlet (921), at least one further fluid outlet, and at least one further passage (923) arranged in the body (901) to guide a further fluid from the further fluid inlet (921) to the further fluid outlet.

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14. A heat exchanger according claim 13, characterized in that the bottom portion (9112) or the top portion (912) presents a cylindrical surface (941), the further passage (923) being arranged to guide the further fluid in an axial direction in relation to the cylindrical surface (941).

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15. A heat exchanger according claim 13, characterized in that the bottom portion (9112) or the top portion (912) presents a cylindrical surface (941), the further passage (923) being arranged to guide the further fluid in a direction with an axial component and a circumferential component in relation to the cylindrical surface (941).

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16. A heat exchanger according to any one of claims 14-15, characterized in that the heat exchanger comprises a plurality of further passages (923) arranged in the body (901) to guide the further fluid from the further fluid inlet (921) to the further fluid outlet, and that an end cavity (924, 925) is provided in an axial end region of the body (901), the end cavity (924, 925) extending circumferentially in relation to the cylindrical surface (941) so as to communicate with at least two of the further passages (923).

30

17. A heat exchanger according to claim 16, characterized in that the further fluid inlet (921) is arranged to introduce the further fluid into the end cavity (924) in a direction with a component in the circumferential direction of the body (901).

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18. A heat exchanger according to claim 13, characterized in that the bottom portion (9112) or the top portion (912) presents a cylindrical surface (941), the further passage (923) being arranged to guide the further fluid in a circumferential direction in relation to the cylindrical surface (941).

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19. A heat exchanger according to any one of claims 13-18, characterized in that the bottom portion (9112) or the top portion (912) presents a cylindrical surface (941), the at least one further passage (923) being entirely located radially inside the walls (9082) or the fins (9081).

10

20. A heat exchanger according to any one of claims 13-19, characterized in that the bottom portion (9112) or the top portion (912) presents a cylindrical surface (941), the top portion (912) forms an outer member (912), and the bottom portion (911) forms a part of an intermediate member (911) located concentrically with and radially inside the outer member (912), the body (901) further comprising an inner member (913) located concentrically with and radially inside the intermediate member (911).

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21. A heat exchanger according to claim 20, characterized in that the at least one further passage (923) is provided as a plurality of further passages (923), and that the further passages (923) are formed on an outer surface of the inner member (913) and/or an inner surface of the intermediate member (911) by a plurality of inner ridges (931, 932) separated by inner grooves.

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22. A heat exchanger according to claim 21, characterized in that a wet surface provided by a plurality of the inner ridges (931) on the inner surface of the intermediate member (911) and a wet surface provided by a plurality of the inner ridges (932) on the outer surface of the inner member (913) are mutually adapted to a desired relationship between a heat transport from the fluid guided between the intermediate member (911) and the outer member (912) to the further fluid and a heat transport from a heat source located radially inside the inner member (913) to the further fluid.

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23. A motor and transmission combination (131, 132) with a transmission cooling circuit (133), characterized in that the combination comprises a heat exchanger

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5 according to any one of claims 13-22, wherein the transmission cooling circuit (133) is arranged to communicate with the fluid inlet (902) and the fluid outlet (903), wherein the body (901) encloses the motor (131), the at least one further passage (923) being entirely located radially inside the walls (9082) or the fins (9081).

24. A working machine comprising a combination according to claim 23 at at least one wheel hub of the working machine for propulsion of the working machine.

10 25. A heat exchanger characterized in that the heat exchanger comprises a first member (911) with a surface presenting a plurality of ridges (931) separated by grooves, and a second member (913) positioned adjacent the first member (911) whereby the heat exchanger is arranged to guide a cooling fluid between the first and second members (911, 913), the second member (913) presenting on a
15 surface facing said surface of the first member (911) a plurality of ridges (932) separated by grooves.

26. A heat exchanger according to claim 25, characterized in that a wet surface provided by the ridges (931) of the first member (911) and a wet surface provided
20 by the ridges (932) of the second member (913) being mutually adapted to a desired relationship between a heat transport from a first element, located on a side of the first member (911) which is opposite to the side on which the second member (913) is located, to the cooling fluid, and a heat transport from a second element, located on a side of the second member (913) which is opposite to the
25 side on which the first member (911) is located, to the cooling fluid.

27. A heat exchanger according to any one of claims 25-26, characterized in that the first and second member (913) are cylindrical and the second member (913) is positioned coaxially to the first member (911) and radially inside the first member.

30

28. A heat exchanger according to claim 27, characterized in that the ridges (931, 932) of the first and second members (911, 913) extend circumferentially.

29. A method for manufacturing a heat exchanger, characterized by the steps of
35 providing (S1, S2) a topological member (911) with a surface presenting a plurality

of ridges (907) separated by grooves (9061), providing (S3) a plurality of depressions (908) in each of a plurality of the ridges (907) so that each depression extends from a groove on one side of the respective ridge to a groove on the opposite side of the respective ridge, positioning (S6) a closing member (912) in relation to the topological member (911) so as for the grooves (9061) and the depressions (908) to provide passageways (906, 9084) for a cooling fluid between the topological member (911) and the closing member (912).

30. A method according to claim 29, characterized in that the depressions (908) are provided (S3) subsequently to the provision of the topological member (911) with the surface presenting the plurality of ridges (907) separated by grooves (9061).

31. A method according to any one of claims 29-30, characterized in that the topological member (911) is provided by extrusion (S1).

32. A method according to any one of claims 29-31, characterized in that the topological member (911) and the closing member (912) are cylindrical, and the closing member (912) is positioned coaxially with the topological member (911).

33. A method according to claim 32, characterized in that the ridges (907) extend in the axial direction of the topological member (911).

34. A method according to claim 32, characterized in that the ridges (907) extend in a direction with an axial components as well as a circumferential component in relation to the topological member (911).

35. A method according to any one of claims 32-34, characterized in that said surface is an external surface of the topological member (911), and the closing member (912) is positioned radially outside the topological member (911).

36. A method according to any one of claims 29-35, characterized in that the depressions (908) are provided by use of a lathe (S3) in the ridges (907).

37. A method according to any one of claims 29-36, characterized by providing (S4) a complementary member (913) with a surface presenting a plurality of ridges (932)

5 separated by grooves, positioning (S7) the complementary member (913) on a side of the topological member (911) which is opposite to a side on which the closing member (912) is positioned, so as for the grooves of the complementary member (913) to provide passages for a further cooling fluid between the complementary member (913) and the topological member (911).

10 38. A method according to any one of claims 29-37, characterized by providing on a surface of the topological member (911), which is opposite to said surface of the topological member (911) presenting a plurality of ridges (907) separated by grooves (9061), a plurality of further ridges (931) separated by further grooves, positioning a complementary member (913) in relation to the topological member (911) so as for the further grooves of the topological member (911) to provide passages for a further cooling fluid between the topological member (911) and the complementary member (913).

15

20 39. A method according to claims 37 and 38, characterized by determining a relationship between a heat transport from the cooling fluid between the topological member (911) and the closing member (912) to the further cooling fluid and a heat transport from a heat source on a side of the complementary member (913), which is opposite to the side on which the topological member (911) is provided, to the further cooling fluid, and mutually adapting a wet surface provided by the ridges (931) of the topological member (911) and a wet surface provided by the ridges (932) of the complementary member (913) to said determined heat transport relationship.

25

30 40. A method according to any one of claims 37-39, characterized in that the topological member (911), the closing member (912) and the complementary member (913) are cylindrical and positioned mutually concentrically with the closing member (912) radially outside the topological member (911) and the complementary member (913) radially inside the topological member (911).

35 41. A method for manufacturing a heat exchanger, characterized by the steps of providing by extrusion (S1, S4) a cylindrical body (911A) with a plurality of surface grooves (9061) separated by ridges (907, 932), cutting (S2, S5) along a radial cross-section the cylindrical body into a plurality of ridged members (911B, 913),

positioning (S6, S7) a cylindrical covering member (911, 912) coaxially with a respective of the ridged members (911, 913) so as for the axial surface grooves (9061) to provide passages for a cooling fluid between the ridged member (911, 913) and the covering member (911, 912).

5

42. A method according to claim 41, characterized in that the surface grooves and the ridges of the cylindrical body are axial.

10

43. A method according to claim 42, characterized in that the surface grooves and the ridges of the cylindrical body extend in a direction with an axial component and a circumferential component.

15

44. A method according to any one of claims 41-43, characterized by creating by use of a lathe (S3) a plurality of circumferentially oriented depressions (908) in each of a plurality of the axial ridges (907).

20

45. A method according to any one of claims 41-44, characterized by removing, at an axial end portion of the respective ridged member (913), material from at least one of the ridges (932), so as for the ridged member and the covering member to provide an end cavity (924, 925) extending circumferentially past the at least one ridge from which material was removed.

25

46. A method for providing a heat exchanger comprising providing a first member (911) with a surface presenting a plurality of ridges (931) separated by grooves, characterized by providing a second member (913) with a surface presenting a plurality of ridges (932) separated by grooves, positioning the second member (913) adjacent the first member (911) so that said surface of the second member (913) faces said surface of the first member (911), so as for the ridges to form passages for a cooling fluid between the first and second members.

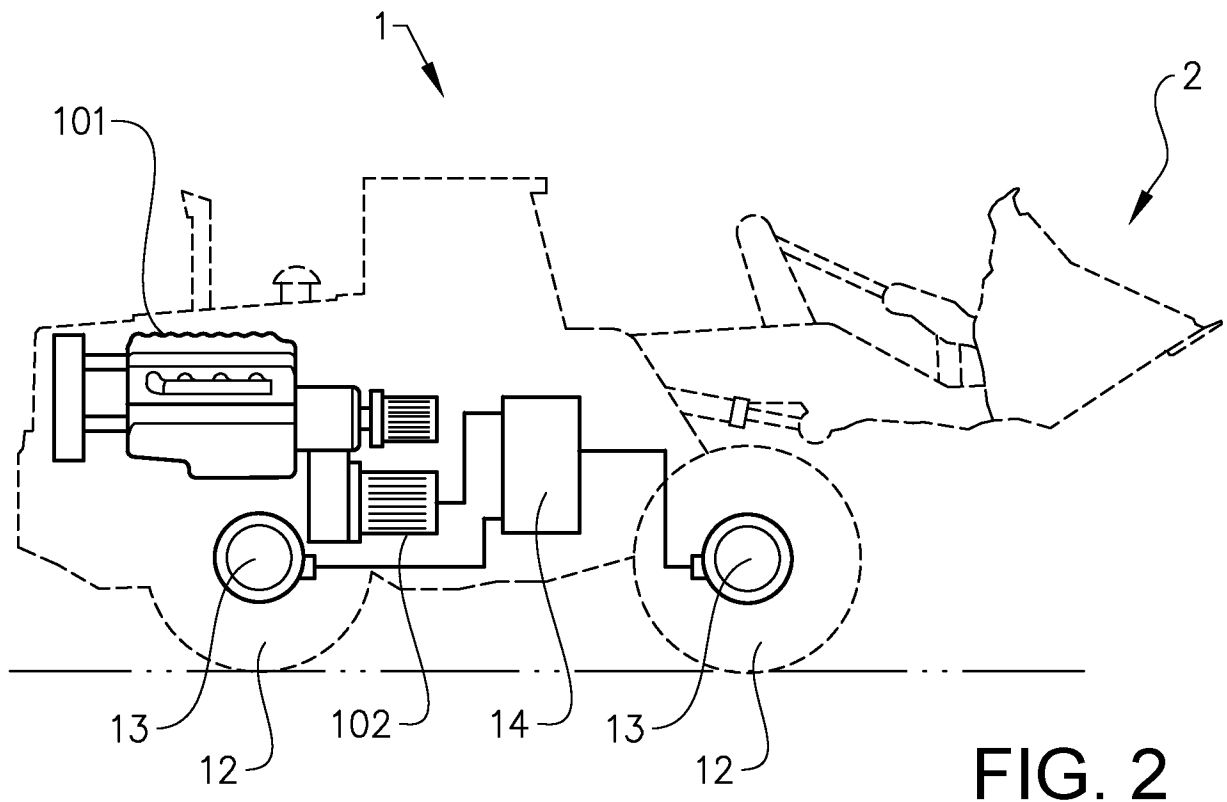
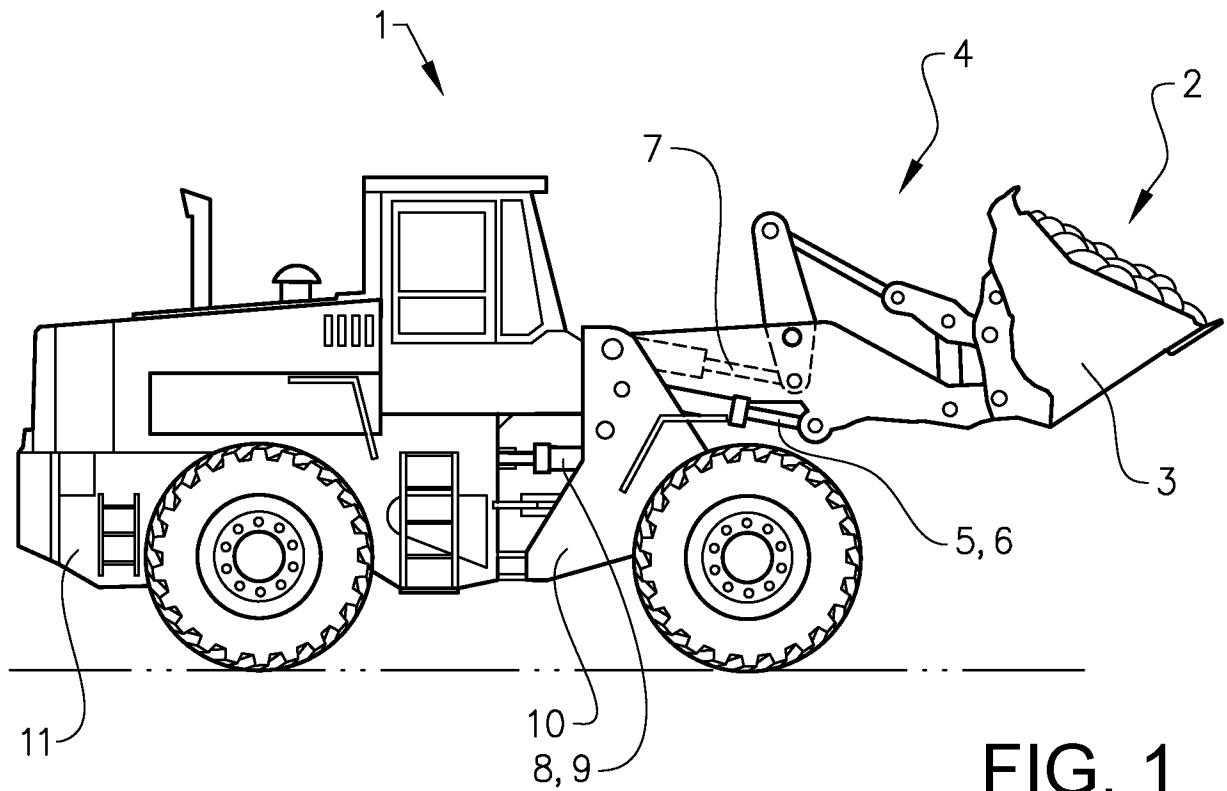
30

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47. A method according to claim 46, characterized by determining (S8) a relationship between a heat transport from a first element, located on a side of the first member (911) which is opposite to the side on which the second member (913) is located, to the cooling fluid, and a heat transport from a second element, located on a side of the second member (913) which is opposite to the side on which the first member (911) is located, to the cooling fluid, and mutually adapting (S9) a wet

surface provided by the ridges (931, 932) of the first and second members to said determined heat transport relationship.

1/11



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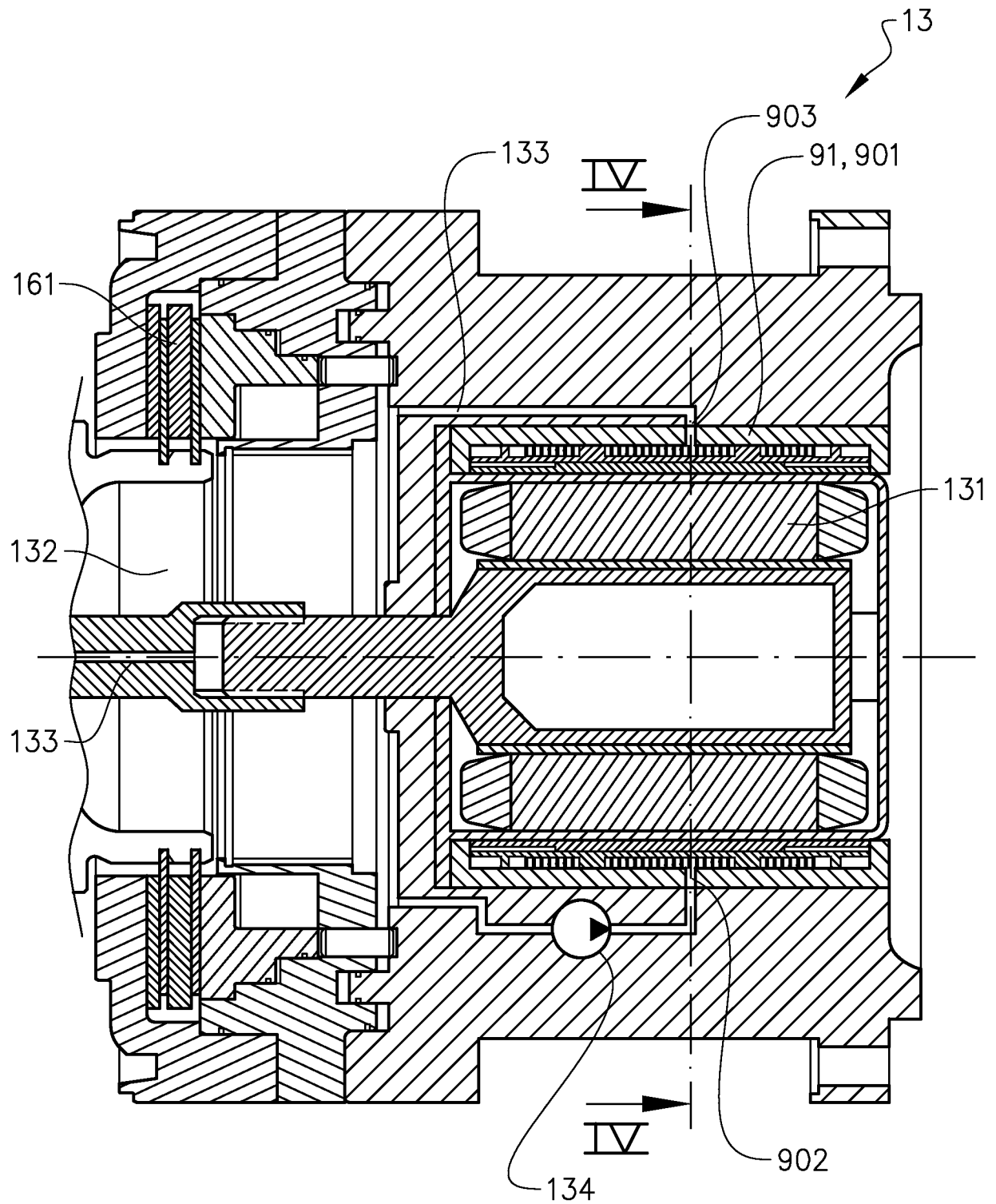


FIG. 3

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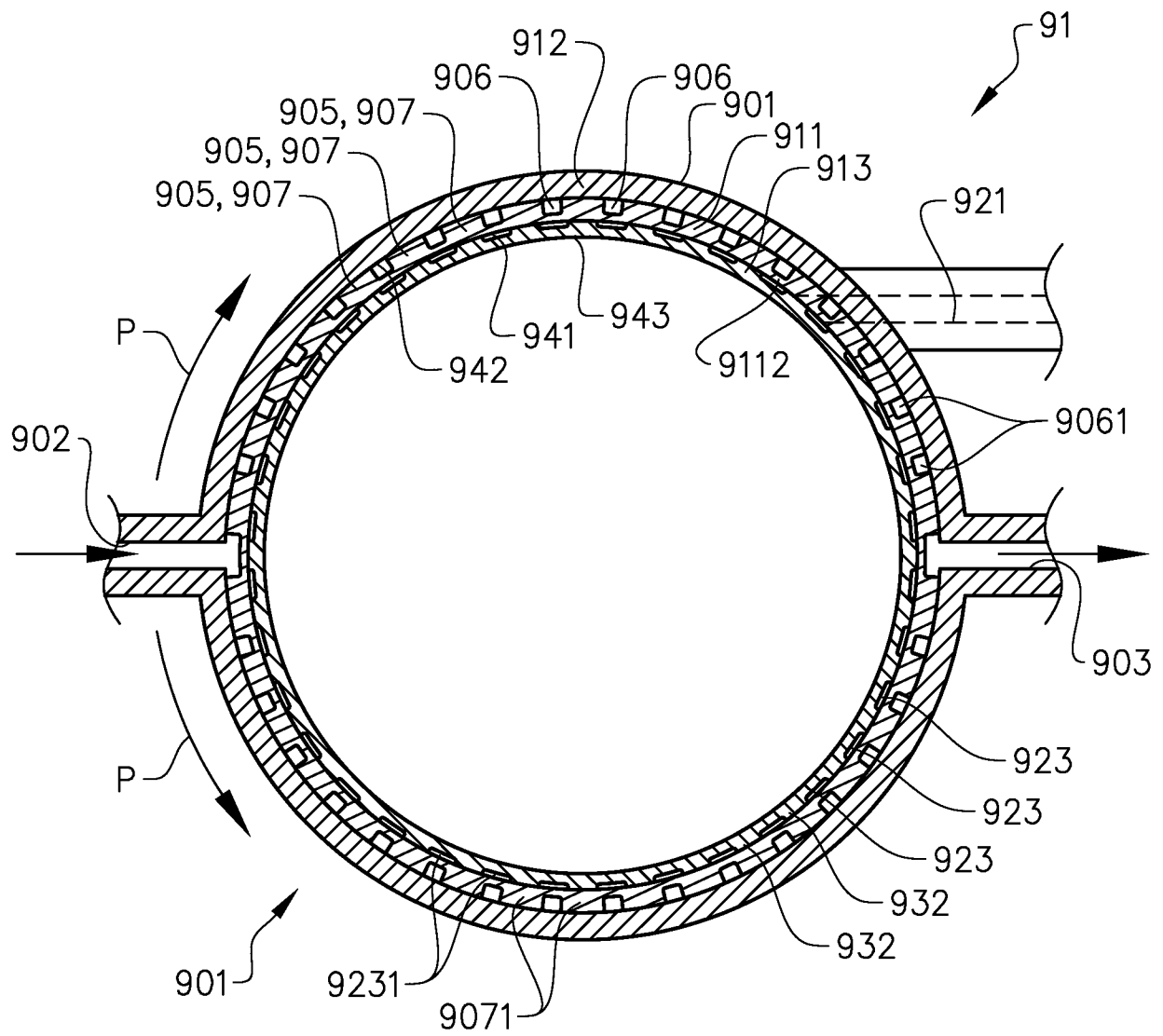


FIG. 4

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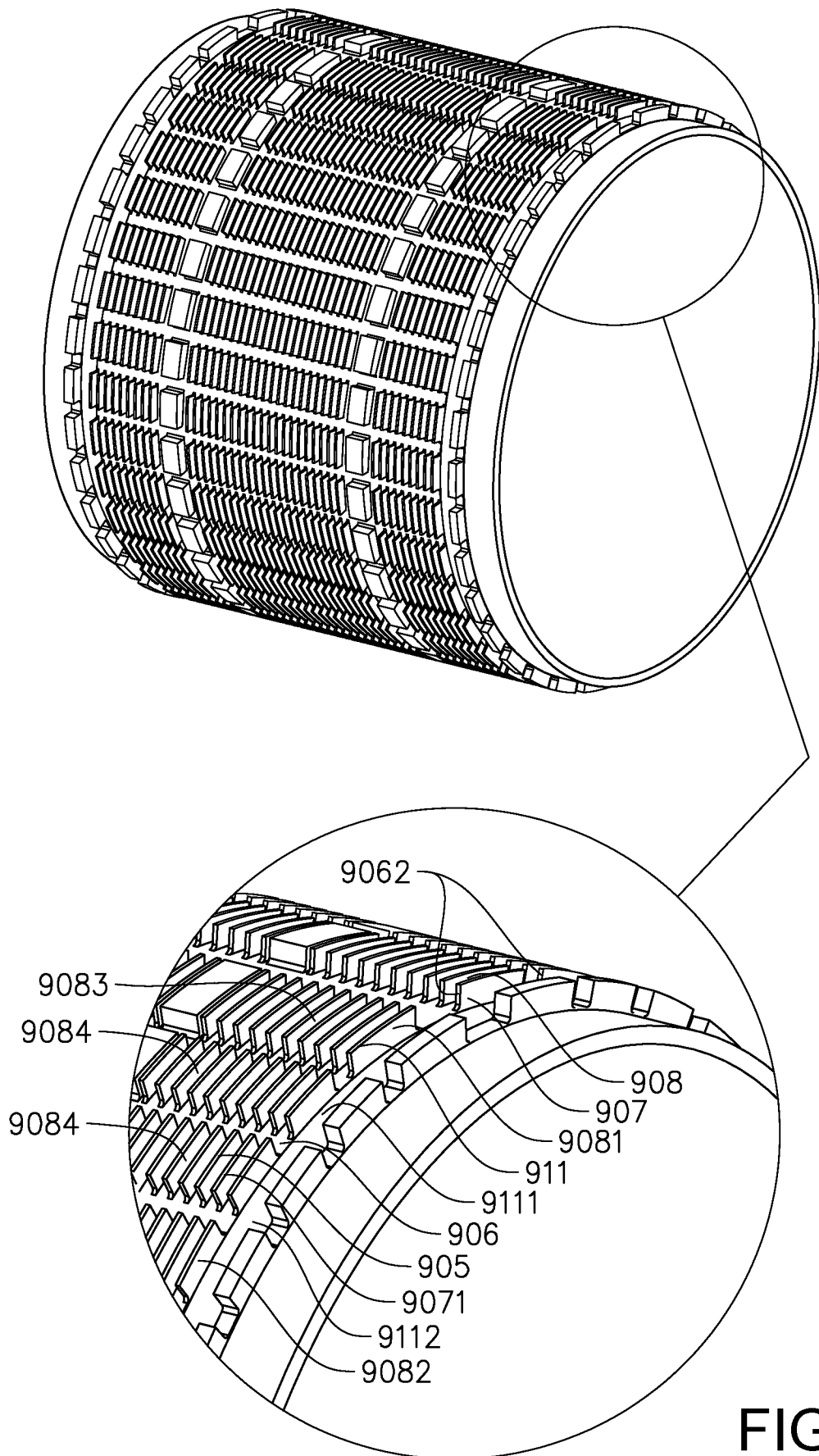


FIG. 5

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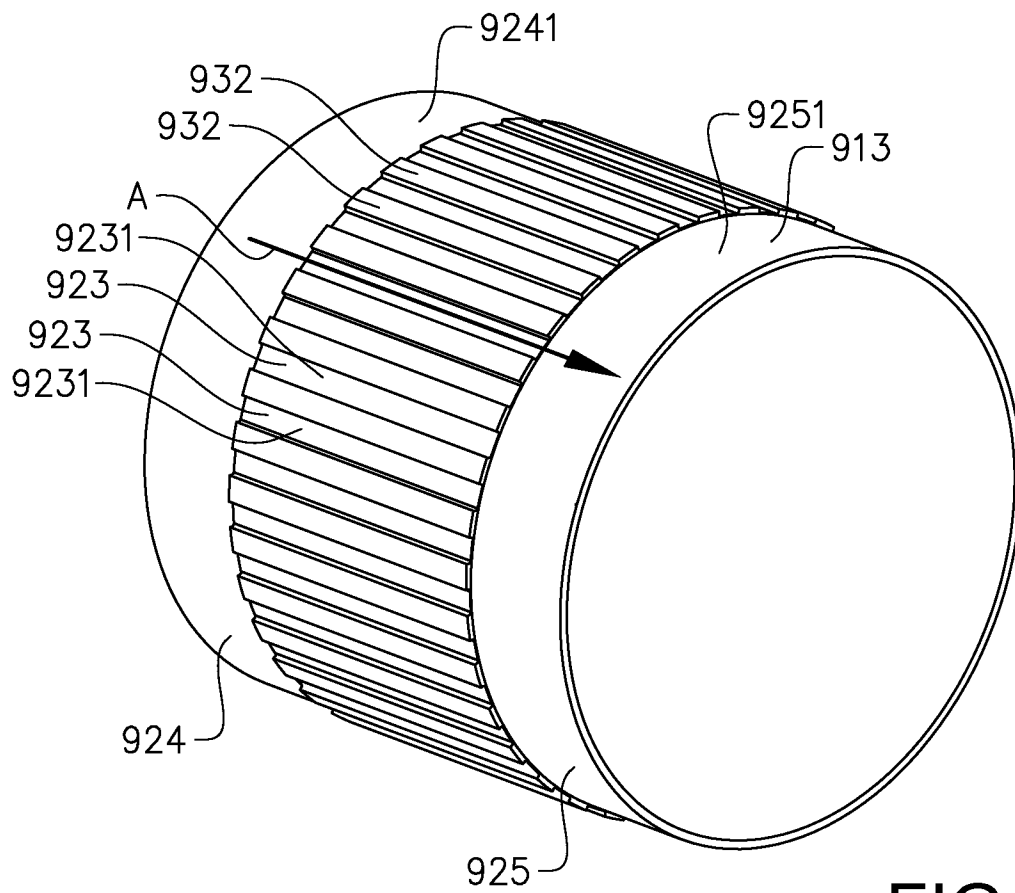


FIG. 6

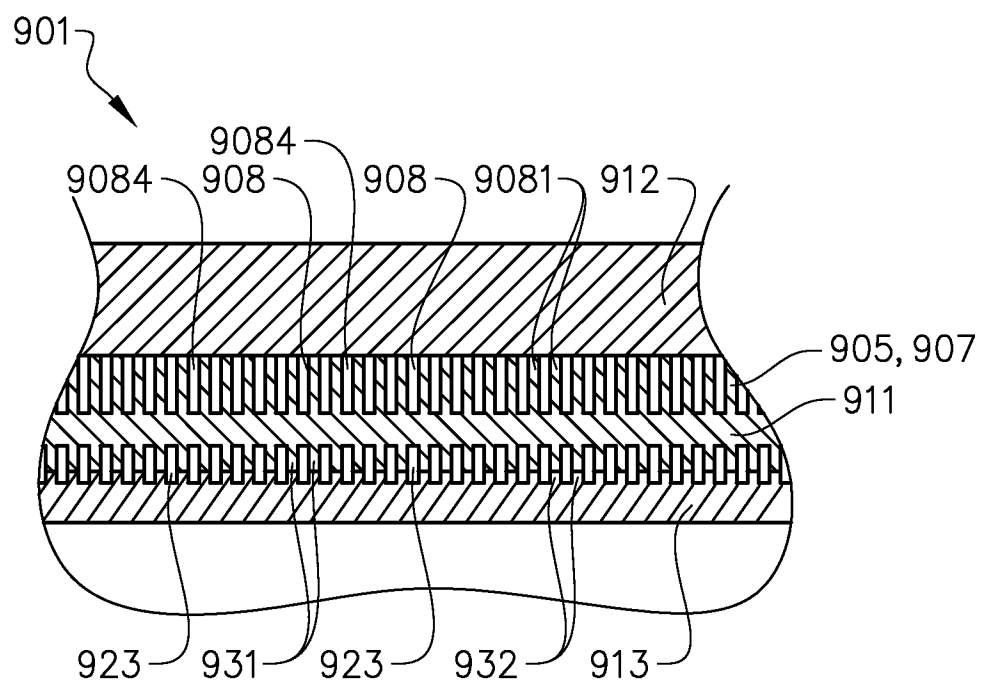


FIG. 7

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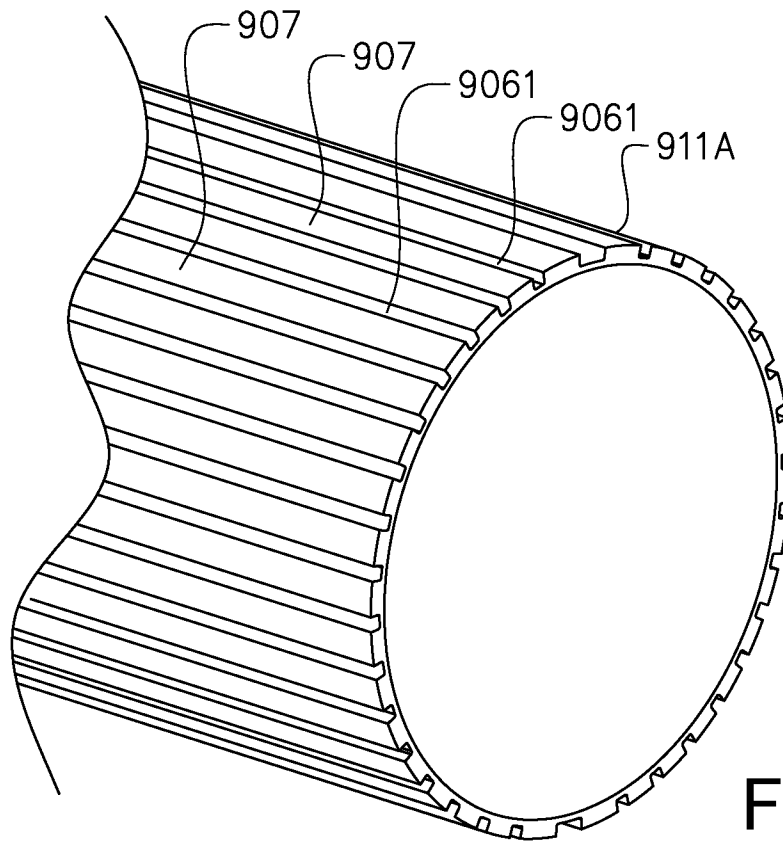


FIG. 8

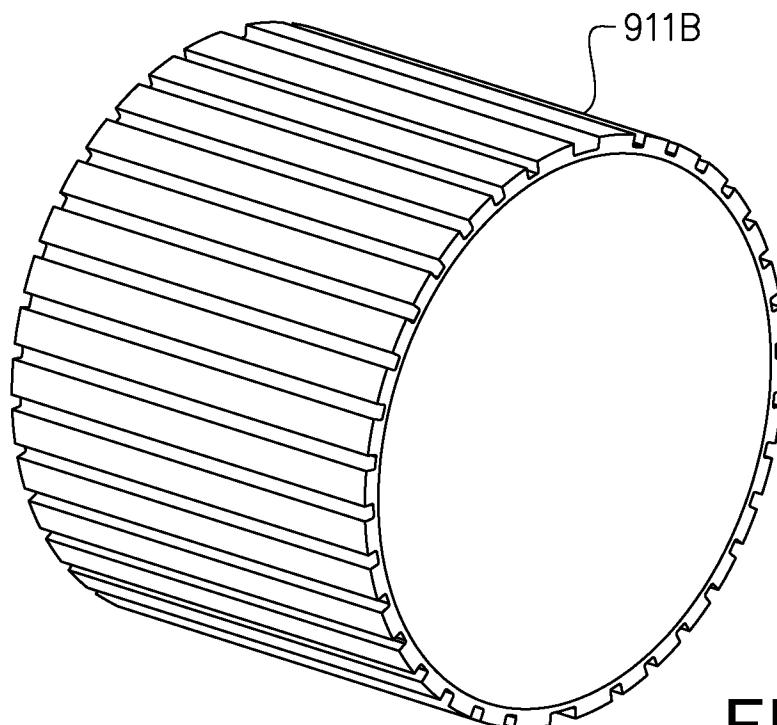


FIG. 9

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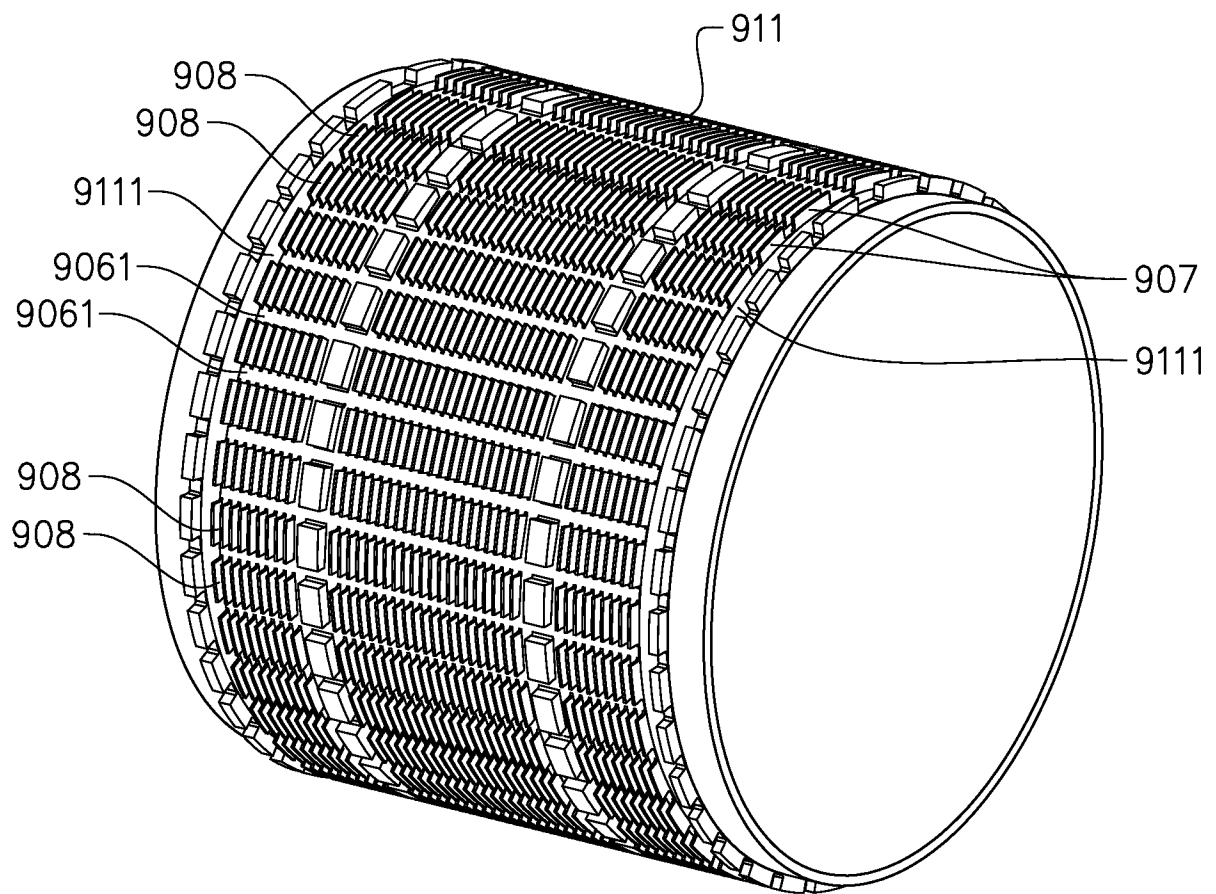


FIG. 10

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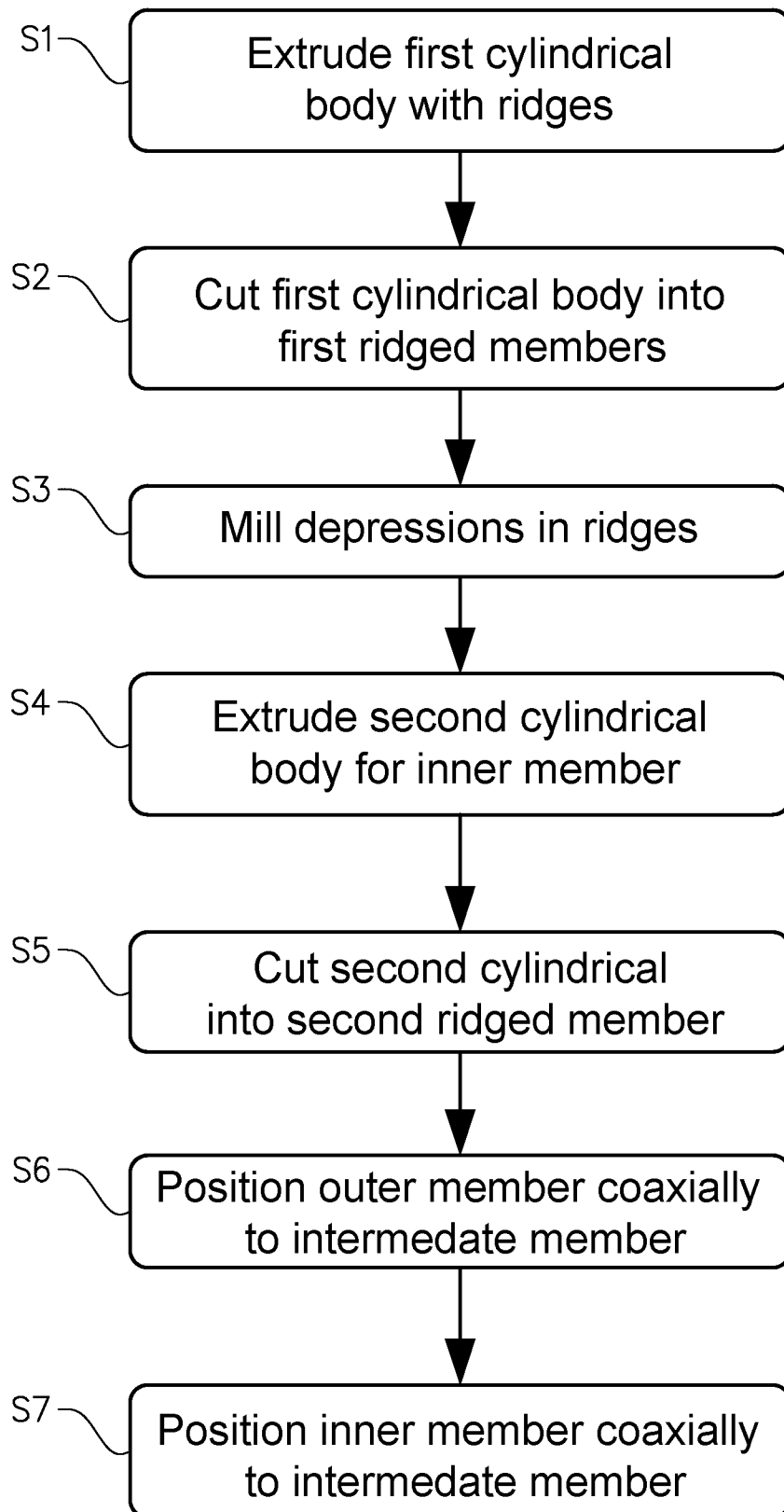


FIG. 11

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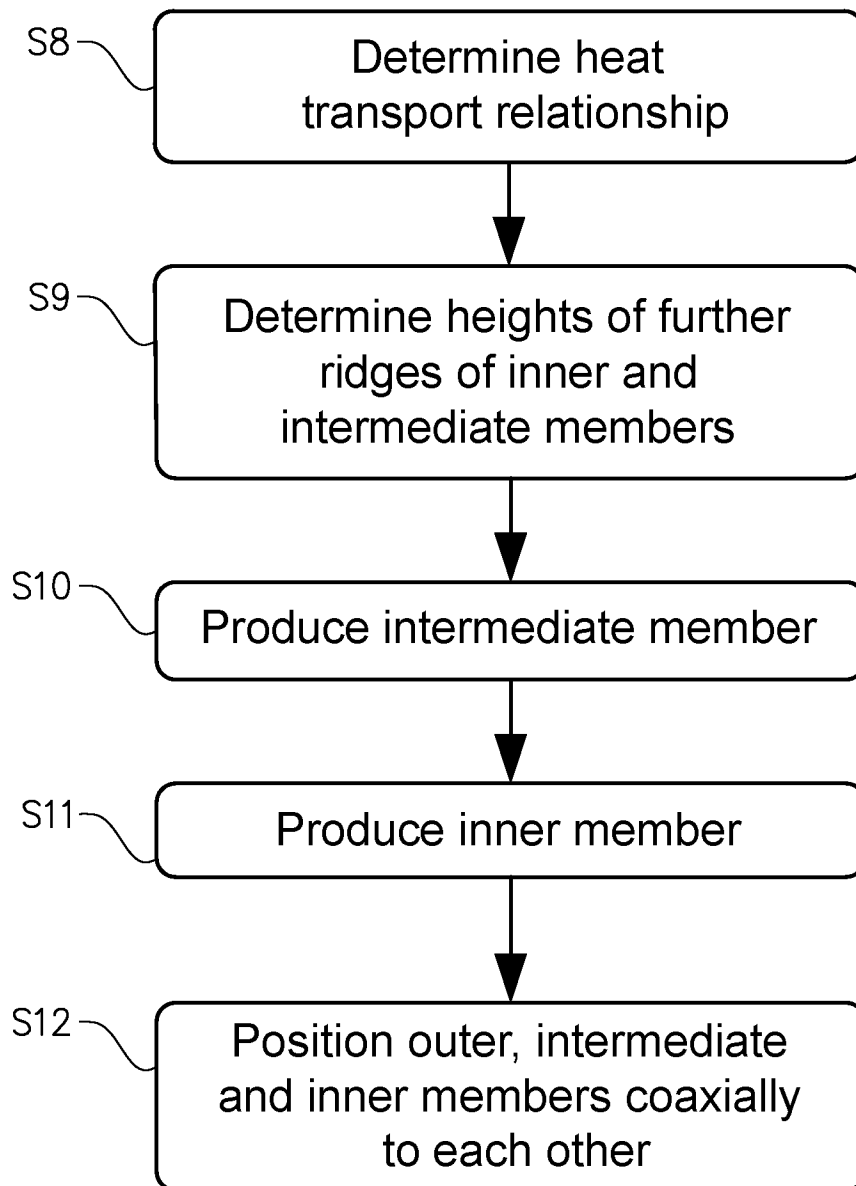


FIG. 12

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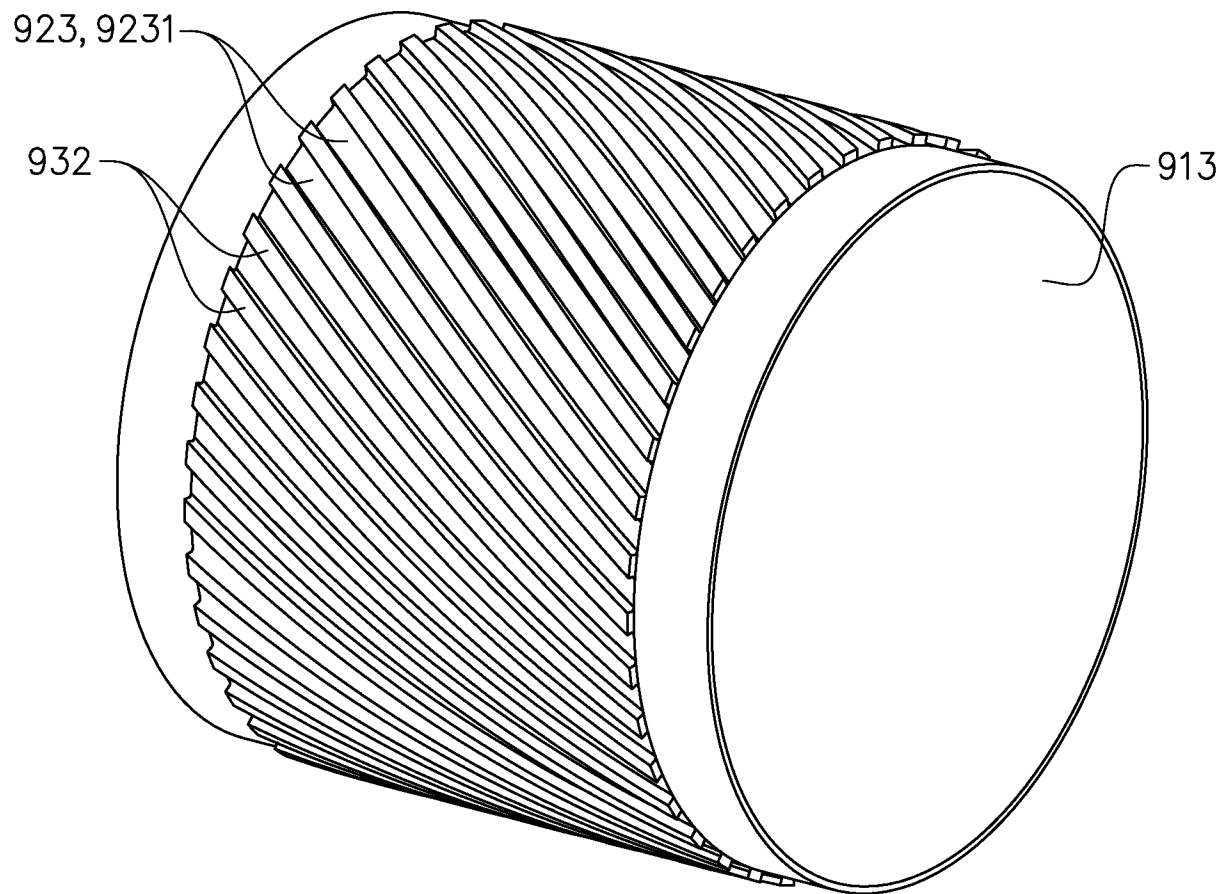


FIG. 13

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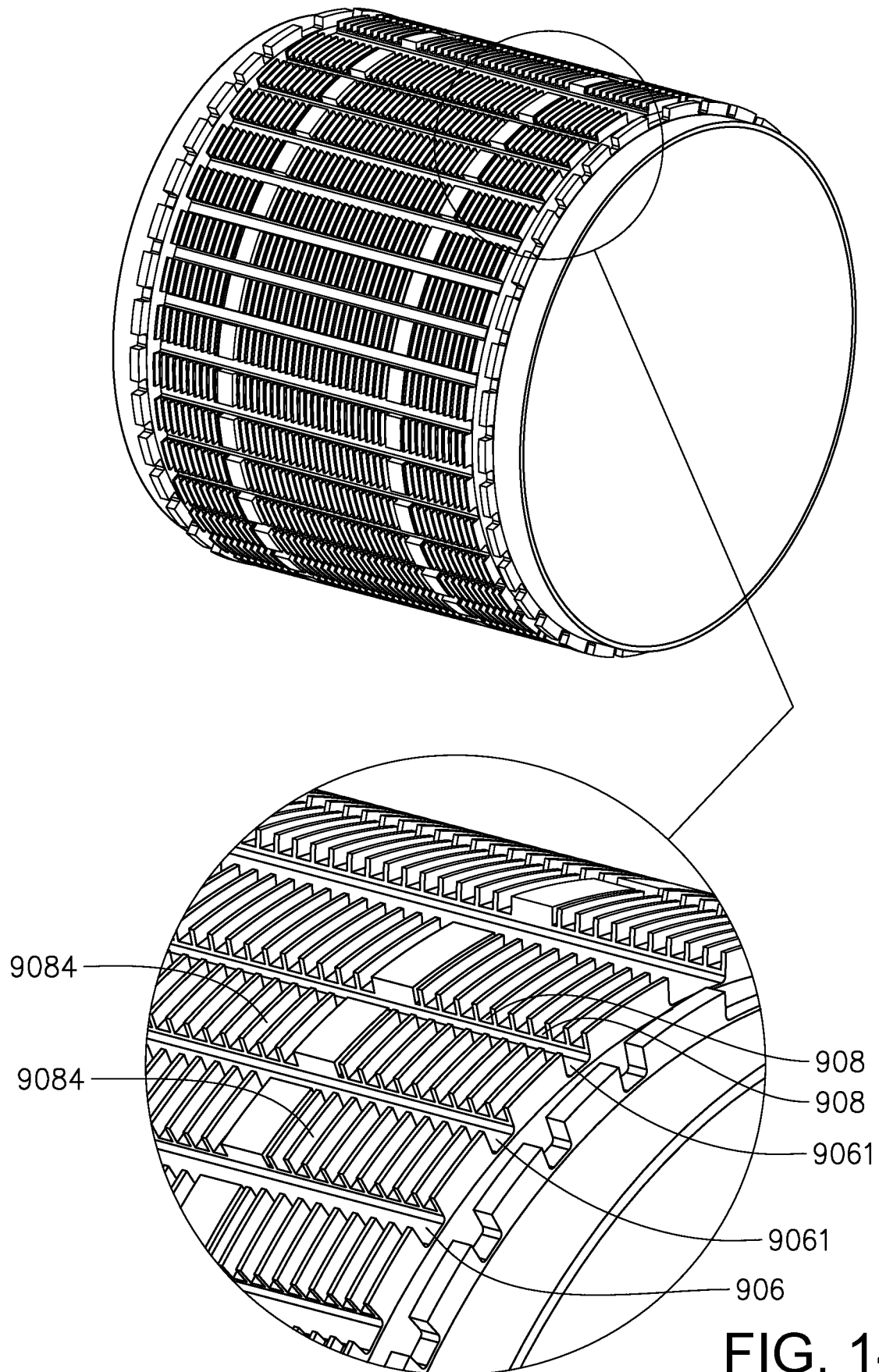


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2016/050726

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B23P, F28D, F28F, H02K

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20120080964 A1 (BRADFIELD MICHAEL D), 5 April 2012 (2012-04-05); abstract; paragraphs [0015]-[0017], [0020]; figures 3, 4A; Especially relevant for invention 1.	1-3, 5-10, 12, 29, 32-33, 35
A	--	4, 11, 13-28, 30-31, 34, 36-47



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T”

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X”

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y”

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&”

document member of the same patent family

Date of the actual completion of the international search

05-06-2017

Date of mailing of the international search report

05-06-2017

Name and mailing address of the ISA/SE

Patent- och registreringsverket

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INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/SE2016/050726

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3887004 A (BECK THEODORE A), 3 June 1975 (1975-06-03); abstract; column 4, line 25 - line 41; column 7, line 48 - column 8, line 2; column 8, line 63 - column 9, line 28; column 10, line 28 - column 11, line 14; figures 2-6; Especially relevant for inventions 1 and 4.	1-11, 29-36, 41-45
A	--	12-28, 37-40, 46-47
X	EP 1916399 A2 (GEN ELECTRIC ET AL), 30 April 2008 (2008-04-30); abstract; paragraphs [0032]-[0037]; figures 3-6; Especially relevant for inventions 1 and 2.	1-3, 5-24, 29-40
A	--	4, 25-28, 41-47
X	US 20120199335 A1 (MAURER SCOTT M), 9 August 2012 (2012-08-09); abstract; paragraphs [0030]-[0037], [0054]; figures 3-4; Especially relevant for inventions 1 and 2.	1-3, 5-8, 13, 29
A	--	4, 9-12, 14-28, 30-47
A	US 20130152392 A1 (SWINFORD MARK DOUGLAS), 20 June 2013 (2013-06-20); abstract; paragraph [0022]; figures 1-2	1-47
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X	US 20160107274 A1 (RIGAL EMMANUEL ET AL), 21 April 2016 (2016-04-21); abstract; paragraphs [0092]-[0116]; figure 2A; Especially relevant to invention 3.	25-28, 46
A	--	1-24, 29-45, 47
X	EP 2369723 A2 (HAMILTON SUNDSTRAND CORP), 28 September 2011 (2011-09-28); abstract; paragraphs [0008]-[0015]; figures; Especially relevant for inventions 1 and 4.	1-3, 5-10, 29, 32-33, 35, 41-45
A	--	4, 11-28, 30-31, 34, 36, 37-40, 46-47

INTERNATIONAL SEARCH REPORT

 International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2490573 A (GM GLOBAL TECH OPERATIONS INC - (B) GM GLOBAL TECH OPERATIONS LLC [US]), 7 November 2012 (2012-11-07); whole document; abstract; figures; See detailed description. Especially relevant for inventions 1 and 4.	1-3, 5-10, 29-33, 35-36, 41-45
A	--	4, 11-28, 34, 37-40, 46-47
X	EP 2058926 A2 (HAMILTON SUNDSTRAND CORP), 13 May 2009 (2009-05-13); abstract; paragraphs [0007]-[0021]; figures; Especially relevant for invention 1.	1-3, 5-10, 29, 32-33, 35
A	--	4, 11-28, 30-31, 34, 36-47
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X	EP 0781610 A2 (SHOWA ALUMINUM CORP - (A3) SHOWA ALUMINUM CORP- (B1) SHOWA DENKO KK [JP]), 2 July 1997 (1997-07-02); whole document; Especially relevant for invention 3.	25-28, 46
A	--	1-24, 29-45, 47
X	US 4461733 A (OTTERBEIN ROY T), 24 July 1984 (1984-07-24); whole document; Especially relevant for invention 3.	25-28, 46
A	--	1-24, 29-45, 47
X	CN 202836268 U (LUOYANG MIDAS ALUMINIUM INDUSTRY CO LTD), 27 March 2013 (2013-03-27); whole document; Especially relevant for invention 4.	41-43, 45
A	--	1-40, 44, 46-47

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2016/050726

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0935063 A2 (SANYO ELECTRIC CO), 11 August 1999 (1999-08-11); whole document -- -----	1-47

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2016/050726

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1: Claims 3-12 and 29-36 directed to a heat exchanger and a method of manufacturing a heat exchanger with a specific arrangement of fins or walls for promoting turbulence in the fluid flowing within the heat exchanger.

2: Claims 13-24 and 37-40 directed to a heat exchanger and a method of manufacturing a heat exchanger consisting of two fluid channels or passages arranged within a common body of the heat exchanger as well as a motor and transmission combination comprising a .../...

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Continuation of: Box No. III

such a heat exchanger and a working machine comprising such a motor and transmission combination.

3: Claims 25-28 and 46-47 directed to a heat exchanger and a method of manufacturing a heat exchanger consisting of a first member and a second member, both arranged with a surface presenting a plurality of ridges separated by grooves, where the surfaces face each other.

4: Claims 41-45 directed to a method of manufacturing a cylindrical heat exchanger with ridges and grooves for guiding a heat exchanging fluid.

Continuation of: second sheet

International Patent Classification (IPC)

H02K 5/20 (2006.01)

B23P 15/26 (2006.01)

F28D 7/10 (2006.01)

F28F 1/22 (2006.01)

F28F 13/12 (2006.01)

H02K 1/32 (2006.01)

H02K 9/19 (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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