CONTROLLABLE COOLING SYSTEM FOR A MOTOR VEHICLE, COOLANT PUMP THEREFORE, IMPELLER FOR USE IN THE COOLANT PUMP, AND METHOD FOR CONTROLLING A COOLANT FLOW IN SUCH A COOLING SYSTEM

Inventor: Franz Pawellek, Laubertal (DE)

Assignee: Gerate- und Pumpenbau GmbH Dr. Eugen Schmidt, Merbelsrod (Thur.) (DE)

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ABSTRACT

The present invention relates to a controllable cooling system (1) for a motor vehicle, comprising a coolant circuit which routes coolant to and out of an internal combustion engine, and to a mechanically operated, controllable main coolant pump (3) and an electrically operated, controllable secondary coolant pump (5). The cooling system further comprises a control device which controls the main coolant pump (3) and the secondary coolant pump (5) in dependence on operating conditions of the internal combustion engine. The invention furthermore provides an electrically operated, controllable secondary coolant pump (5) for such a cooling system (1), an impeller (25) for use in this secondary coolant pump (5), and a method for controlling the coolant flow in such a cooling system (1).
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FIELD OF THE INVENTION

[0001] The present invention relates to a controllable cooling system for a motor vehicle according to claim 1, an electrically operated, controllable coolant pump suitable for use therein according to claim 6, an impeller according to claim 22 for use in the coolant pump, and a method according to claim 30 for controlling a coolant flow in such a cooling system.

PRIOR ART

[0002] Mechanically actuated coolant pumps are generally employed in motor vehicles to circulate coolant in a coolant circuit between vehicle radiator and internal combustion engine. Coolant pumps of this kind, designed as axial flow pumps or radial flow pumps, are thereby arranged between the vehicle radiator and the internal combustion engine.

[0003] The coolant pumps are driven by the driving power of the internal combustion engine via a belt drive. Examples of such pumps are discussed in DE 10 2005 004 315 B4 and DE 10 2005 062 200 B3 of the same applicant.

[0004] Owing to the increasing scarcity of fossil fuels, the focus of current developments in the automotive sector is on ever more fuel-efficient and energy-saving vehicles. Start-stop systems are, for example, used for this which temporarily shut down an internal combustion engine in the vehicle, for example when stopping at a red traffic light, a railway gate, etc. As soon as the stop situation has come to an end, and as when, for example, the traffic light turns green and the vehicle driver actuates the accelerator pedal, the internal combustion engine is restarted.

[0005] However, owing to the system-inherent shut-down of the internal combustion engine in such start-stop systems in modern motor vehicles, the operation of the coolant pump is stopped as well. Owing to the standstill of the internal combustion engine, no driving power is, in particular, transmitted any longer via the belt drive to the coolant pump, causing the operation thereof to be ceased, and so the coolant can no longer be circulated in the coolant circuit.

[0006] Especially at high outside temperatures or correspondingly high engine and/or coolant temperatures, this may cause the temperature to rise beyond the allowed level.

[0007] So that circulation of the coolant in the coolant circuit is continued also in vehicles with start-stop systems when the internal combustion engine is inoperative, it would, in principle, be conceivable to replace the conventionally employed, mechanically operated coolant pumps by electrically operated coolant pumps.

[0008] However, electric coolant pumps exhibit the drawback that they must be dimensioned large enough to provide the cooling capacity. Electrically operated coolant pumps of such large dimensions must then be adequately powered by the on-board power system.

[0009] Since this may possibly have to be compensated via the automotive alternator which must accordingly produce more power to keep the in-vehicle batteries at a minimum battery charge level and to sufficiently supply the on-board power system, the use of electric pumps as coolant pumps for motor vehicles has not as of yet become widespread.

[0010] In order to nonetheless offer a possibility for ensuring sufficient coolant flow with modern start-stop systems, there have been attempts recently to provide an adapted coolant pump by combining electric and mechanical drives.

[0011] One example of such a coolant pump, designated as hybrid coolant pump, is disclosed in the journal MTZ, issue 11, 2010. The hybrid coolant pump discussed therein is driven by the driving power of the internal combustion engine via a belt drive as the main drive. This pump additionally comprises a brushless electric motor in its pump casing that can be appropriately controlled via clutches to connect to the drive shaft, and so either enhances the driving force of the belt drive or solely takes over coolant circulation in the start-stop condition when the internal combustion engine is off.

[0012] The hybrid coolant pump disclosed in MTZ, issue 11, 2010, is not, however, suited to satisfactorily respond to all operating conditions of the internal combustion engine.

[0013] In particular, it is not possible with the coolant pump discussed in MTZ, issue 11, 2010, to ensure a quick warm-up cycle of the internal combustion engine by interrupting the coolant flow without any leakage flow. It is namely impossible with such open coolant pumps to have what is called standing water. A certain basic coolant circulation can in fact always be observed, and therefore an accelerated warm-up operation is not feasible.

[0014] It is true that it is discussed in the article regarding the hybrid coolant pump in MTZ, issue 11, 2010, that pumps of this kind can be unpowered in order thereby to carry out an accelerated warm-up process in the internal combustion engine.

[0015] Nonetheless, it is not possible with the hybrid coolant pump of this design to avoid coolant back-flow or leakage from the pump, which may give rise to a minimum amount of circulation which as such delays the warm-up process.

[0016] Besides, it is not possible with the pump disclosed in MTZ, issue 11, 2010, to set respectively suitable coolant circulation flow rates in dependence on different operating conditions of the internal combustion engines, for example idle mode, overrun mode or the like, which would allow the coolant temperature to be kept in an ideal coolant temperature range for the respective operating condition.

[0017] Also, the pump disclosed in MTZ, issue 11, 2010, exhibits the drawback that when the pump is operated via the pulley, and thus via the internal combustion engine, the electric motor located in the pump casing acts as a generator. The electrical power generated must thus accordingly be routed out of the pump and fed into the on-board power system. In order to avoid the generator action of the electric pump, the latter must, alternatively, be isolated from the shaft whenever operation of the electric pump is not required.

[0018] This renders the construction of such a hybrid pump even more complex, increasing the costs for the system beyond economically viable levels. The efficiency achievable with a pump of this kind is also rather low compared with conventional systems.

SUMMARY OF THE INVENTION

[0019] Starting out from the drawbacks of the previously described prior art, the present invention is based on the object of providing a cooling system of simple construction which allows a flow of coolant to be easily ensured in a coolant circuit of an internal combustion engine even when...
the internal combustion engine is unpowered. The present invention is further supposed to provide a cooling system by means of which different cooling effects can be achieved in dependence on different operating conditions of the internal combustion engine.

[0020] This object is attained by the cooling system according to claim 1.

[0021] In accordance with the invention, a controllable cooling system for a motor vehicle is proposed which comprises a coolant circuit for supplying and discharging coolant to and from an internal combustion engine of the vehicle. In this cooling system there is arranged a mechanically operated, controllable main coolant pump comprising an inlet for supplying the coolant into the main coolant pump and an outlet for discharging the coolant to the internal combustion engine, and an electrically operated, controllable secondary coolant pump comprising an inlet for supplying the coolant into the secondary coolant pump and an outlet for discharging toward the main coolant pump a coolant conveyed as a bypass coolant flow, wherein the secondary coolant pump is arranged upstream of the main coolant pump in the direction of flow, forked off from a coolant line leading to the main coolant pump in the direction of coolant flow. The coolant conveyed by means of the secondary coolant pump is supplied, downstream of the main coolant pump and without flowing therethrough, into the outlet leading to the internal combustion engine. The secondary coolant pump further comprises a pump casing with a pump chamber formed therein, wherein a section of the pump casing an electric motor is arranged which provides driving power for the secondary coolant pump by means of a drive shaft extending into the pump chamber. An impeller serving as a conveyor member is arranged in the pump chamber of the secondary coolant pump and is coaxially arranged on the drive shaft and drivably connected thereto, wherein the secondary coolant pump comprises a control slide valve formed on the impeller which can be moved at least to open and closed positions, for controlling the bypass coolant flow conveyed by the secondary coolant pump, particularly for preventing back-flow of the coolant in a direction opposite to the conveying direction of the secondary coolant pump.

[0022] The following advantages can be achieved by means of the cooling system according to the invention.

[0023] The parallel use of a mechanical pump as main coolant pump and an electric pump as secondary coolant pump allows a cooling system to be provided in an astonishingly simple and inexpensive way which features a simple construction and allows a flow of coolant to be easily ensured in a coolant circuit of an internal combustion engine even when the internal combustion engine is unpowered and thus unable to generate driving power for the mechanically operated main coolant pump.

[0024] Here, the mechanically operated coolant pump which has proven its worth in practice is advantageously retained in the cooling system, and this allows high levels of efficiency to be achieved whenever operating the cooling system by the mechanical pump, optionally supported by the electric pump. The levels of efficiency achievable with the cooling system according to the invention are significantly higher than is the case for a single-shaft hybrid pump discussed above.

[0025] Furthermore, the cooling system according to the invention, comprising the two discussed controllable pumps, advantageously makes it possible to have what is called standing water, which enables the internal combustion engine to warm up quickly, particularly when started cold, with the result that the vehicle can be operated at an optimal temperature/fuel consumption level within a very short period of time.

[0026] It can be advantageously ensured by controlling the slide valve in the secondary coolant pump and particularly by moving the slide valve to its closed position, that any coolant streaming back from the internal combustion engine due to the absence or deactivation of pumping action flows in a direction opposite to the conveying direction of the secondary coolant pump, towards the vehicle radiator.

[0027] It is furthermore possible by using the already known, mechanically operated, controllable main coolant pump and the additional, parallel arrangement of the controllable, electrically operated secondary coolant pump to implement a cooling system which ensures reliable cooling performance in modern, fuel-saving engine concepts including, for example, automatic start-stop systems, engine shutdown in the coasting mode, or the like, whilst keeping development and application costs within reason.

[0028] Furthermore, the integral design of the mechanically operated and electrically operated coolant pumps does not make it necessary thereby, as discussed for the aforementioned hybrid pump disclosed in MTZ, issue 11, 2010, to implement new bearing and sealing systems for the water pump shaft, whose suitability for continuous, long-term operation and economic efficiency will become apparent only after a few years.

[0029] It is, on the contrary, possible with the cooling system according to the invention to resort to bearing and sealing systems which have proven their worth in many ways in practice, whereby a reliable and economical operation of the cooling system can be ensured.

[0030] Further embodiments of the cooling system according to the invention are the subject matter of the sub-claims.

[0031] According to an embodiment, the main coolant pump comprises a pump casing with a pump chamber formed therein, wherein an impeller serving as a conveyor member is arranged in the pump chamber and is driven via a shaft extending into the pump chamber which is preferably driven by a belt drive.

[0032] According to an embodiment, the main coolant pump can thereby be designed as an axial flow pump or radial flow pump.

[0033] The fact that the main coolant pump is driven via a pulley connected to a pulley of the internal combustion engine advantageously makes it possible to drive the main coolant pump without any additional drive units. Moreover, the use of the belt drive which is driven by the running internal combustion engine entails almost no frictional loss, and therefore the main coolant pump can be operated at high efficiency.

[0034] Furthermore, using the belt drive which utilizes the driving power of the internal combustion engine offers the advantage of still allowing rotational motion of the impeller in the main coolant pump to be produced even at low rpm of the internal combustion engine, thus ensuring coolant circulation even at low rpm and so reliably avoiding overheating of the motor.

[0035] According to another embodiment, the main coolant pump further comprises a control slide valve formed on the impeller and arranged coaxially with respect thereto, which can be moved, preferably along the impeller mounted in the
pump chamber, at least to open and closed positions, to control the coolant flow conveyed by the main coolant pump. [0036] It is advantageously possible by means of the control slide valve which, according to the invention, is arranged in the main coolant pump to deliberately interrupt the coolant flow without thereby interrupting the operation of the main coolant pump. It is namely possible in this manner, for example in order to have standing water on cold start of the internal combustion engine, to move the slide valve to its closed position in which it encloses the impeller and prevents further transfer of the coolant out of the point of discharge, thus interrupting the coolant flow being conveyed by the impeller.

[0037] The arrangement of such a slide valve coaxially to the impeller moreover simplifies the overall construction of the main coolant pump. Namely, no freewheel or the like is necessary to interrupt the transmission of driving power from the internal combustion engine to the drive shaft of the main coolant pump. Instead, it is possible by displacing the control slide valve along the drive shaft of the main coolant pump to interrupt coolant circulation through the main coolant pump, without thereby suspending the transmission of driving power from the internal combustion engine to the drive shaft of the main coolant pump.

[0038] According to an embodiment, the electric motor of the secondary coolant pump is configured as a dry rotor or as a wet rotor. [0039] The use of an electric motor designed as a dry rotor for the secondary coolant pump thereby advantageously enables high rpm of the secondary coolant pump and minimum size.

[0040] The alternative use of an electric motor designed as a wet rotor for the secondary coolant pump ensures comparatively simple cooling of the electric motor since the coolant which is present in the vehicle cooling circuit anyway can be used therefor.

[0041] The use of electric motors of this kind advantageously makes it possible to provide a secondary coolant pump designed as a standard electric pump which, whilst having a small size, allows high quantities to be produced at low manufacturing costs.

[0042] According to another embodiment, the cooling system further comprises a control device which controls the main coolant pump and/or the secondary coolant pump in dependence on assigned operating conditions of the internal combustion engine.

[0043] The control device provided in accordance with the invention, which is implemented, for example, as a software module in the vehicle control unit or designed as an independent control unit, advantageously makes it possible to control the main coolant pump and/or the secondary coolant pump in parallel or independently of one another, to thereby always produce a desired flow of coolant in the cooling circuit.

[0044] It is in particular possible thereby to control the main coolant pump and/or the secondary coolant pump so that these are throttled to such a point during the warm-up operation on cold start of the internal combustion engine that no coolant is circulated. As soon as the internal combustion engine has reached its operating temperature, the pumps can be controlled in parallel or separately from one another to control coolant flow by appropriately displacing the control slide valve arranged in the respective pump chamber.

[0045] It is advantageously possible by means of this control and by using maps, to actively control the coolant temperature in dependence on specific operating conditions of the internal combustion engine, for example when this is idling, or of the vehicle, for example on city driving, such that the coolant temperature can be maintained at a level at which optimum fuel utilization and thus an economical and efficient operation of the vehicle can be realized.

[0046] It is another aspect of the present invention to offer an electrically operated coolant pump suited for such a cooling system.

[0047] The advantages that are achievable with the cooling system discussed above can be analogously achieved also with the electric coolant pump according to the invention discussed hereinafter, and therefore these advantages will not be enumerated again.

[0048] An electrically operated coolant pump according to an embodiment of the invention which is suitable, in particular, for use in a cooling system discussed above is designed as an axial flow pump or radial flow pump. The electrically operated coolant pump comprises: a pump casing; a preferably flange-like inlet and a preferably flange-like outlet; a pump chamber formed in the pump casing, wherein a pump wheel is arranged on a pump shaft in the pump chamber, the pump wheel being drivable by an electric motor through the intermediary of the pump shaft; and a slide valve that is displaceable at least to open and closed positions, for controlling a bypass coolant flow conveyed by the coolant pump. The electrically operated pump according to the invention can be controlled in such a manner that back-flow of the coolant from the internal combustion engine in a direction opposite to the conveying direction of the secondary coolant pump can be prevented when the control slide valve is in the closed position.

[0049] It can be advantageously ensured by controlling the slide valve in the electrically operated pump so that to travel to its closed position that any coolant streaming back from the internal combustion engine due to the absence or deactivation of pumping action flows in a direction opposite to the conveying direction of the coolant pump, towards the vehicle radiator.

[0050] As regards the parallel connection of two pumps, it should be noted that the parallel flow paths also form bypass flow paths. The medium to be conveyed always flows in the direction of lower pressure.

[0051] Since the main coolant pump builds up a clearly higher delivery pressure during operation, it can be ensured by displacing the control slide valve of the secondary coolant pump to its closed position that back-flow from the discharge side of the main pump via the secondary pump to the suction side is prevented when the main pump is active.

[0052] According to an embodiment, the electric coolant pump is designed as a radial flow pump, wherein the coolant to be conveyed, diverted from a coolant line, can be introduced into the pump chamber formed in the pump casing through the substantially conically extending inlet, and the coolant introduced into the pump chamber can be discharged from the pump chamber through the outlet arranged substantially at a right angle radially to the inlet line.

[0053] The pump wheel which is designed as a radial flow pump impeller and arranged in the pump chamber sucks in the coolant by rotational movement in an axial direction and conveys the coolant into the outlet in a radial direction. The slide valve is designed as a control slide valve arranged on the impeller, coaxially to the pump shaft; and the electric motor is arranged on a section of the pump casing which preferably
faces away from the inlet; wherein the electric motor comprises a drive shaft projecting into the pump chamber, the impeller and the control slide valve are coaxially arranged on the drive shaft and retained on the drive shaft in a positive fit manner, preferably by means of retaining elements, and the control slide valve is cylindrically designed, enclosing the impeller, and is displaceable in an axial direction of the impeller to open and closed positions.

According to an embodiment, the control slide valve is connected to the impeller in such a manner as to be penetrated by impeller blades.

It is possible thereby to significantly reduce the space required for the electric coolant pump since the assembly comprises of the impeller and the control slide valve has a compact design.

According to an embodiment, the electric motor is configured as a dry rotor and sealed from the pump chamber by means of a shaft seal arranged on the drive shaft. In an alternative embodiment, the electric motor is configured as a wet rotor and is cooled by the coolant conveyed by the coolant pump.

According to an embodiment, the control slide valve is displaced, via at least one actuator provided in the pump casing, to its open and/or closed position. This actuator may thereby be designed as a pneumatically, magnetically and/or hydraulically operated slide valve or as an electric servomotor.

In an example embodiment, the actuator may be arranged in a frontal area of the drive shaft and engage into a section formed on the front side of the control slide valve and having a compartment-like shape, to displace the control slide valve relative to the impeller to its open and closed positions.

Alternatively, or additionally, the actuator may also be arranged between the impeller and the control slide valve. For example, the actuator is a rocker arm which connects the impeller to the control slide valve and can be hydraulically, pneumatically or magnetically moved from its rest position abutting the impeller (the open position of the control slide valve) to a position spaced from the impeller (the closed position of the control slide valve).

The actuator may also be formed in the wall of the pump casing, for example in recesses or compartments provided to this end.

According to another embodiment, the control slide valve comprises a compartment-like section, enclosing the drive shaft, which faces towards the inlet and has a threaded section formed on its inner periphery, wherein a threaded section complementary to the threaded section of the control slide valve is formed on a section of the drive shaft of the electric coolant pump facing away from the electric motor. In accordance with the invention, the control slide valve is displaceable along the drive shaft by mutual engagement of the threaded sections.

Due to the provision of the complementary threaded sections, an additional drive mechanism for the control slide valve in the electric coolant pump can be advantageously avoided, allowing the space required for the pump to be reduced while further reducing costs and simplifying the pump construction.

According to another embodiment, the control slide valve is designed to follow the contour of the front side of the impeller and has arranged at its outer end a radially continuous closure member, wherein a first sealing member, arranged radially outside the control slide valve, is disposed at an end of the closure member facing away from the electric motor.

According to another embodiment of the electric coolant pump, a receptacle into which the closure member of the control slide valve can be introduced in the open position thereof is formed in the pump chamber.

The provision of this receptacle allows the size of the coolant pump to be further reduced in an advantageous manner since no additional space needs to be provided inside the pump chamber for the closure member of the control slide valve.

According to an embodiment of the coolant pump, a second sealing member, arranged radially inside the control slide valve, is disposed on a radially outer end of the impeller which faces towards the electric motor. In accordance with a preferred embodiment, the diameter of the first sealing member may thereby be designed larger than the diameter of the second sealing member.

According to an embodiment, the outlet of the electric pump can be tightly closed, via the closure member, the first sealing member and the second sealing member, by the control slide valve when this is in the closed position.

The configuration of the control slide valve such that it follows the contour of the front side of the impeller permits a compact design of the assembly of impeller and control slide valve. The provision of the sealing members on the control slide valve and on the impeller furthermore allows the outlet of the electric pump to be safely sealed in an advantageous manner when the control slide valve is in the closed position, whereby at the same time, when the control slide valve is in the closed position, the closure member of the control slide valve is supported against the impeller in such a manner that any back pressure possibly generated by the coolant is unable to move or bend the control slide valve open so as to cause leakage flow in the coolant pump.

In another embodiment of the coolant pump according to the invention, there is further provided a braking member, by means of which the impeller can be secured to an inner wall of the pump casing.

According to an embodiment, the braking member is thereby formed on the impeller and preferably consists of a pretensioned brake spring or plate-like brake disc which preferably comprises at its radially outer ends, in a radially inward direction, substantially wedge-tapered thickening, wherein the braking member can be preferably brought into frictional engagement with the inner wall of the pump casing adjoining the electric motor by means of the thickening, to secure the impeller to the pump casing.

According to another embodiment, the braking member, including, in particular, the thickenings thereof, is designed to disconnect from the inner wall of the pump casing as the speed of rotation of the impeller caused by the drive shaft of the electric motor increases, so as to disengage the impeller.

With this arrangement, it is possible in an advantageously easy manner to secure the impeller to the pump chamber wall, whereby only the control slide valve is displaceable to its open or closed position on rotation of the drive shaft.

When the control slide valve has arrived in its fully open position, an interference fit is created between the impeller sitting on the drive shaft and the control slide valve, with the result that rotation of the drive shaft is transmitted to the impeller. As the speed of rotation of the drive shaft
increases, the braking member disconnects from the pump chamber wall due to centrifugal forces, enabling rotation of the impeller. This advantageously permits reliable displacement of the control slide valve along the drive shaft, without thereby rotating the impeller as well.

[0074] Moreover, a kind of start-up operation can be advantageously realized when the control slide valve and the impeller are engaged and rotation of the drive shaft is transmitted to the impeller as a result of interference fit between the impeller and the control slide valve. This allows the delivery rate of the electric coolant pump to be gently increased.

[0075] The invention moreover provides a suitable impeller and a method for controlling a coolant flow in a cooling system according to the invention.

[0076] The advantages discussed above apply analogously also to the impeller according to the invention and to the method for controlling the coolant flow in a cooling system.

[0077] According to an embodiment, the impeller comprises: a plurality of blades that are preferably typically of radial flow pumps and formed on the impeller surface facing towards a coolant inlet; a recess for receiving a drive shaft; a control slide valve connected to the impeller, and a braking member arranged on the impeller.

[0078] The impeller according to the invention is advantageously suitable for use in a coolant pump according to the invention as discussed above as well as in a corresponding cooling system comprising this coolant pump.

[0079] In an embodiment of the impeller, the control slide valve comprises at its front end a first sealing member arranged radially outside thereof, wherein the impeller comprises at its radially outer end a second sealing member arranged radially inside the control slide valve.

[0080] According to another embodiment, the control slide valve is configured integrally with the impeller such that the impeller blades penetrate the control slide valve in an axial direction.

[0081] In another embodiment of the impeller according to the invention, the braking member is formed on a back side surface of the impeller.

[0082] In accordance with the embodiment according to the invention, the braking member consists of a pretensioned brake spring or plate-like brake disc capable of being brought into frictional engagement with a surface opposite the back side surface of the impeller, to secure the impeller to this surface.

[0083] According to another embodiment, the braking member is designed such that its braking effect decreases as the speed of rotation of the impeller increases, whereby it approaches the back side surface of the impeller to disengage the impeller.

[0084] In another embodiment of the impeller according to the invention, the control slide valve is designed to follow the contour of the impeller and comprises at its outer end a radially continuous closure member.

[0085] According to an embodiment, the control slide valve comprises in its frontal area a hollow, compartment-like section with a threaded section formed on the inner circumferential wall thereof.

[0086] According to an embodiment, a method according to the invention for controlling a coolant flow in a cooling system of a motor vehicle, wherein the cooling system comprises a controllable main coolant pump mechanically operated by the driving power of an internal combustion engine arranged in the vehicle and a controllable secondary coolant pump electrically operated by a separately arranged electric motor, comprises the steps of: detecting a current operating condition of an internal combustion engine of the vehicle; detecting a coolant temperature of a coolant circulating in a coolant circuit of the vehicle; reading out control parameters from a cooling circuit map; controlling the main coolant pump and the secondary coolant pump based on the control parameters read out from the cooling circuit map; and controlling the coolant flow by selectively switching the main coolant pump and/or the secondary coolant pump.

[0087] According to an advantageous embodiment of the method according to the invention, the current operating condition of the internal combustion engine includes at least a start-stop condition, a warm-up condition, a low-load condition, a normal-load condition, an eco condition, a high-rpm condition, and a residual heat storing condition.

[0088] The start-stop condition refers to a powered condition in which the internal combustion engine is temporarily stopped, for example at a red traffic light or the like, to thereby save fuel.

[0089] The warm-up condition refers to a powered condition in which, particularly on cold start of the internal combustion engine, an interruption of the coolant circulation causes the water to stand still in the cooling system, so that the temperature of the internal combustion engine can be quickly brought to its optimum operating temperature.

[0090] The low-load condition refers to a powered condition in which the internal combustion engine is operated at low rpm, for example at idle.

[0091] The normal-load condition refers to a powered condition in which the internal combustion engine is preferably operated in the mid-rpm range to apply driving power to the vehicle.

[0092] The eco condition refers to a powered condition in which the internal combustion engine is operated normally and the coolant temperature is maintained at an elevated level by a control intervention in the cooling system, thus enabling more efficient fuel combustion and hence improved fuel economy.

[0093] The high-rpm condition refers to a powered condition in which the internal combustion engine is operated at high rpm with increased need for cooling, for example on highway driving or the like.

[0094] The residual heat storing condition refers, in the end, to a powered condition in which the internal combustion engine is off and the coolant temperature is supposed to be kept high for as long as possible in order to reduce the warm-up phase on restarting the internal combustion engine, which enables the internal combustion engine to be operated sooner at its optimum temperature range.

[0095] According to an embodiment, the control parameters in the cooling circuit map include at least a desired coolant temperature, and/or a desired motor temperature, and/or a desired coolant flow rate, and/or the like.

[0096] In accordance with an embodiment of the method according to the invention, when the current operating condition of the internal combustion engine is a warm-up condition, the secondary coolant pump is switched to an OFF-mode condition with the control slide valve closed and a flow of coolant through the main coolant pump is interrupted by means of a control slide valve arranged in the main coolant pump, such that coolant circulation is interrupted.

[0097] In accordance with an embodiment of the method according to the invention, when the current operating con-
tion of the internal combustion engine is a start-stop condition in which the main coolant pump is temporarily unpowered during a stop phase of the internal combustion engine, the secondary coolant pump is switched to an ON-mode condition, by means of which the coolant is circulated through the secondary coolant pump.

[0098] In accordance with an embodiment of the method according to the invention, when the current operating condition of the internal combustion engine is a low-load condition, a flow of coolant through the main coolant pump is interrupted by means of a control slide valve arranged in the main coolant pump and the secondary coolant pump is switched to an ON-mode condition, by means of which the coolant is circulated through the secondary coolant pump.

[0099] In accordance with an embodiment of the method according to the invention, when the current operating condition of the internal combustion engine is a normal-load condition, the secondary coolant pump is switched to an OFF-mode condition and the control slide valve thereof is closed, by means of which the coolant in the coolant circuit is circulated by the main coolant pump.

[0100] In accordance with an embodiment of the method according to the invention, when the current operating condition of the internal combustion engine is an eco condition, operation of the main coolant pump is selectively interrupted by means of an overrunning clutch provided on the belt drive system of the main coolant pump, or a control slide valve arranged in the main coolant pump is controlled such that the coolant flow in the main coolant pump is interrupted and the coolant is circulated through the secondary coolant pump so that a desired elevated motor temperature is obtained.

[0101] In accordance with an embodiment of the method according to the invention, when the current operating condition of the internal combustion engine is the high-rpm condition, the coolant flow of the main coolant pump is routed, at least in part, in the bypass mode via the secondary coolant pump to the intake side of the main coolant pump.

[0102] In accordance with an embodiment of the method according to the invention, when the current operating condition of the internal combustion engine is the residual heat storing condition with the internal combustion engine at a standstill, both the control slide valve of the main coolant pump and the control slide valve of the secondary coolant pump are closed in order to prevent circulation of the coolant in the cooling circuit.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0110] FIG. 3C is a detail view of section B of FIG. 3A;

[0111] FIG. 4 is a representation in perspective of an impeller according to the invention with a control slide valve arranged thereon;

[0112] FIG. 5 is a partial sectional representation of the view of FIG. 4 showing a section through the control slide valve; and

[0113] FIG. 6 is a sectional representation of the impeller with the slide valve of FIG. 4 arranged thereon.

FIG. 1A shows a representation in perspective of a controllable cooling system according to an embodiment of the present invention.

[0114] The cooling system 1 according to this embodiment consists of a coolant circuit for supplying and discharging coolant from and to an internal combustion engine (not shown) of a vehicle, wherein the coolant engages in heat exchange with the vehicle surroundings via a radiator (not shown) arranged in the coolant line.

[0115] FIG. 1 shows a detail view of section A of FIG. 1 and are discussed, for example, in the documents DE 10 2005 004 315 B4, DE 10 2005 002 200 B3 and WO 2009/14382 A2.

BRIEF DESCRIPTION OF THE DRAWINGS

[0104] FIG. 1A shows a front view in perspective of a controllable cooling system according to the invention;

[0105] FIG. 1B shows a rear view in perspective of a controllable cooling system according to the invention;

[0106] FIG. 2A is a partial sectional view of an electrically operated coolant pump according to an embodiment of the invention in an open position;

[0107] FIG. 2B is a detail view of section A of FIG. 2A;

[0108] FIG. 3A is a partial sectional view of an electrically operated coolant pump according to an embodiment of the invention in a closed position;

[0109] FIG. 3B is a detail view of section A of FIG. 3A;

[0110] FIG. 3C is a detail view of section B of FIG. 3A;

[0111] FIG. 4 is a representation in perspective of an impeller according to the invention with a control slide valve arranged thereon;

[0112] FIG. 5 is a partial sectional representation of the view of FIG. 4 showing a section through the control slide valve; and

[0113] FIG. 6 is a sectional representation of the impeller with the slide valve of FIG. 4 arranged thereon.
[0123] As is also depicted in FIG. 1A, the main coolant pump 3 of this embodiment comprises the outlet 15 via which the coolant is conveyed from the main coolant pump 3 to the internal combustion engine.

[0124] In addition, a heating circuit may also be provided in the cooling system which can be used to introduce a cooling medium from the main coolant pump 3 into the heating circuit via a heating cable 19. For example, a regulator or valve may be arranged in the main coolant pump 3 which directs the coolant flow conveyed by the pump 3 into the heating circuit.

[0125] The coolant coming out of the vehicle radiator is supplied to the main coolant pump 3 via the coolant line 13 leading to the main coolant pump 3.

[0126] A secondary coolant pump 5 is arranged in parallel to the main coolant pump 3. The inlet 9 to the secondary coolant pump 5 thereby forks off from the coolant line 13 at a point upstream of the inlet 17 of the main pump 3.

[0127] In this embodiment, the secondary coolant pump 5 is likewise designed as an axially supplied, radially conveying pump and is operated by an electric motor 7 arranged on a section of the secondary coolant pump 5 facing away from the coolant inlet 9.

[0128] The coolant delivered from the feed line 13 is sucked into the secondary coolant pump 5 via the conically tapered inlet 9 through the sucking action of an impeller 25 arranged in the secondary coolant pump 5 and is carried from there, via the impeller 25 arranged in a pump chamber 53 and via the outlet 11, into the outlet 15 of the main coolant pump 3, without thereby flowing through the main pump 3. The secondary coolant pump 5 thus forms some kind of bypass path through which the coolant to be conveyed can be circulated in the cooling circuit as a bypass coolant flow from the radiator to the internal combustion engine by circumventing the main coolant pump 5.

[0129] The inlet 9 and the outlet 11 of the secondary coolant pump in the shown embodiment are designed in a flange-like manner. They can, however, also be designed in the form of a line, nipple, aperture, screw or bayonet connector, or the like.

[0130] A partial sectional view of the electrically operated coolant pump 5 shown in FIGS. 1A and 1B is represented in FIG. 2A.

[0131] As described previously, the coolant pump 5 shown in FIG. 2A is thereby designed as an axially supplied radial flow pump and comprises a pump chamber 53 formed in a pump casing 51.

[0132] In the embodiment shown in FIG. 2A, an electric motor 7 is arranged at an end of the secondary coolant pump 5 facing away from the inlet 9. The electric motor of this embodiment thereby has a power output between 20 W and 100 W and is designed as a dry rotor, which enables high engine speeds in excess of 12,000 rpm and low power consumption.

[0133] Starting from this motor 7, a drive shaft 21 protrudes into the pump chamber 51 of the secondary coolant pump 5.

[0134] In the embodiment shown here, the drive shaft 21 is sealed against the coolant via a shaft seal 29 to avoid ingress of coolant into the electric motor 7.

[0135] The impeller 25 and a control slide valve 31 are arranged concentrically on the drive shaft 21. The impeller 25 is thereby retained on the drive shaft in a positive fit manner by retaining members 47.

[0136] The shape of the control slide valve 31 thereby substantially follows the contour of the frontal area of the impeller 25, with the blades 39 penetrating the upper side of the control slide valve.

[0137] On a front section of the control slide valve 31 there is formed a sleeve-shaped or compartment-like section 33 having a threaded section provided on the circumference of its inner wall.

[0138] A threaded section complementary thereto is formed on a front section 23 of the drive shaft 21.

[0139] FIG. 2A shows the secondary coolant pump 5 in a condition in which the control slide valve 31 is open.

[0140] In the condition shown in FIG. 2A, the coolant being conveyed by the impeller 25 can thus be carried radially outwardly of the secondary coolant pump 5.

[0141] As is shown in the detail view of section A of FIG. 2A, a sealing member 45 is arranged at a radially outer end of the impeller 25, inside a closure member 35 of the control slide valve 31. Another sealing member 43 is arranged on the radially outer front side of the control slide valve 31.

[0142] Furthermore, a recess 37 which receives the closure member 35 and follows the circumferential contour of the control slide valve 31 in a circle is arranged in the pump casing wall facing towards the electric motor 7. In the open position of the control slide valve 31, the closure member 35 formed therein is received and rotatably held in this receptacle 37, such that the impeller 25 is able, along with the control slide valve 31 formed therein, to rotate through the driving force of the drive shaft 21.

[0143] FIG. 3A shows the electrically operated, controllable secondary coolant pump 5 of FIGS. 2A and 2B with the control slide valve 31 in the closed position.

[0144] As is schematically indicated in FIGS. 2A and 3A, the drive shaft 21 of the electric motor 7 displaces the control slide valve 31 of the coolant pump 5 to the respective working position by slowly rotating forwards and backwards, respectively.

[0145] In particular, by slowly rotating in a forward direction, that is in the pump direction of the coolant pump 5, the drive shaft 21 moves the control slide valve 31 from its closed position to the open position in which it follows the contour of the impeller 25, abutting the surface thereof, such that the impeller blades 39 can penetrate the control slide valve 31 and create the pumping action in the coolant pump 5 when the impeller is rotating at working speed.

[0146] In particular, as soon as the control slide valve 31 comes into contact with the impeller 25, an interference fit is created between the control slide valve 31 and the impeller 25, allowing the impeller 25 to be rotated by the driving power transmitted from the drive shaft 21 to the control slide valve 31. In the open position shown in FIG. 2A, the coolant being conveyed by the impeller 25 can thus be carried out of the coolant pump 5.

[0147] As opposed to this, when reverse rotation of the drive shaft 21 moves the control slide valve 31 to the closed position shown in FIG. 3A, the control slide valve 31 in its fully closed position comes into contact with a wall section of the pump casing 51 facing towards the inlet 9.

[0148] The sealing member 43 formed on the control slide valve 31 is thereby pressed against the pump casing wall and seals the pump chamber 53 with respect to the outlet 11 of the pump 5. The sealing member 45 formed on the rear section of the impeller 25 supports from below the closure member 35.
designed as an outer circumferential leg of the control slide valve 31, to thus produce a sufficiently reliable sealing effect.

As is schematically indicated in FIGS. 2B and 3B, the sealing member 43 formed on the control slide valve 31 is designed larger than the sealing member 45 formed on the impeller 25, to achieve sufficient sealing effect relative to the wall surface of the pump chamber. In particular, due to the different seal diameters, the back-pressure from the discharge side of the main coolant pump 3 bears down on the annular area resulting from the differences in diameter of the sealing members 43, 45. The sealing function of the sealing members 43, 45 is thereby hydraulically amplified irrespective of whether or not the electric motor 7 of the secondary coolant pump 5 is running.

To avoid inadvertent rotation of the impeller 25, a braking member 27 is arranged at an end of the impeller 25 facing away from the inlet 9, said braking member 27 pressing against an inner wall surface 49 in the pump casing 51 which is contiguous with the electric motor 7.

This braking member 27 is thereby designed as a brake disc or pretensioned disc spring and in the shown embodiment has wedge-tapered thickenings 41 at its radially outwards that frictionally engage the inner wall surface 49 of the pump casing 51.

As long as the drive shaft 21 of the electric motor 7 rotates at a slow pace to thereby move the control slide valve 31 to its open position, the braking member 27 keeps the impeller 25 in frictional engagement with the pump casing 51, thus preventing for the most part rotation of the impeller 25.

When there is an interference fit between the control slide valve 31 and the impeller 25 and the rotation of the drive shaft 21 is increasing, the braking member 27 disconnects from the wall 49 of the pump casing 51 due to the increasing centrifugal force produced by the rotation of the drive shaft 21 and so enables rotation of the impeller 25 and thus the pump function of the coolant pump 5.

FIG. 4 is a view in perspective of the impeller 25, shown in FIGS. 2 and 3, of the electrically controllable coolant pump 5 with a control slide valve 31 arranged thereon.

As is shown in this front view, the control slide valve 31 completely encloses the impeller 25 (not shown in detail), with the impeller blades 39 penetrating the control slide valve 31.

The control slide valve 31 comprises in its centre a compartment-like section 33 for receiving the drive shaft 21 of the electric motor 7. As is schematically indicated in FIG. 5, this compartment-like section 33 has a threaded section on its inner wall which is complementary to the threaded section 23 (not shown in FIG. 5) of the drive shaft 21.

FIG. 5 is a partial sectional view of an axially supplied, radially conveying impeller 25 as is used in a pump 3, 5 designed as a radial flow pump in the presently discussed embodiment.

If the coolant pumps 3, 5 are designed as axial flow pumps, it is, however, also conceivable for the impeller to be radially supplied and to convey the coolant forward in an axial direction.

In the centre of the impeller 25, a hub-like receptacle 55 is formed for receiving the drive shaft 21 (not shown).

FIG. 6 is a full sectional representation of the impeller 25 of FIG. 5 with the control slide valve 31 arranged thereon. As is apparent therefrom, the impeller 25 and the control slide valve 31 are arranged concentrically with respect to one another and extend along the drive shaft 21 extending from the electric motor 7 into the pump chamber 51 which are not shown here for the sake of greater clarity.

The control slide valve 31 can be moved to the desired open or closed position by forward and backward rotation, respectively, of the drive shaft 21 of the electric motor 7.

The cooling system according to the invention, which uses the mechanically operated, controllable coolant pump 3 and the electrically operated, controllable coolant pump 5, makes it possible in an advantageous manner to set various operating conditions by taking account of predetermined control parameters such as a desired coolant temperature, and/or a desired motor temperature, and/or a desired coolant flow rate, and/or the like.

Therefore, to control the cooling system 1, a control device is additionally provided in accordance with the presently discussed embodiment which controls the mechanically operated main coolant pump 3 and the electrically operated secondary coolant pump 5 so as to reach the respective operating conditions.

Exemplary operating conditions thereby include a start-stop condition, a warm-up condition, a low-load condition, a normal-load condition, an eco condition, a high-rpm condition, as well as a residual heat storing condition.

The start-stop condition refers to a powered condition in which the internal combustion engine is temporarily stopped, for example when coming to a standstill at a red traffic light or the like, to thereby save fuel.

If the coolant system 1 herein discussed is used in a vehicle comprising a start-stop control and the internal combustion engine is stopped, for example at a red traffic light, the electric coolant pump 5 is able to circulate the coolant all by itself since the mechanically operated coolant pump 3 is no longer being actuated due to the standstill of the internal combustion engine.

For this purpose, when the current operating condition of the internal combustion engine is the start-stop condition in which the main coolant pump 3 is temporarily unpowered during a stop phase of the internal combustion engine, the secondary coolant pump 5 is switched, in accordance with the presently discussed embodiment, to an ON-mode condition, as a result of which the coolant is circulated through the secondary coolant pump 5.

Furthermore, the warm-up condition refers to a powered condition in which, particularly on cold start of the internal combustion engine, an interruption of the coolant circulation causes the water to stand still in the cooling system 1, such that the internal combustion engine can be quickly brought to its optimum operating temperature.

When the current operating condition of the internal combustion engine is the warm-up condition, the secondary coolant pump 5 is switched here to an OFF-mode condition and a flow of coolant through the main coolant pump 3 is interrupted by means of the control slide valve arranged in the main coolant pump, thus interrupting coolant circulation.

It is thereby possible with the cooling system 1 of the presently discussed embodiment to control the pumps 3, 5 in the warm-up phase of the internal combustion engine in such a manner that the slide valves of both pumps 3, 5 are closed and no coolant can be circulated through the two pumps 3, 5. The electrically operated coolant pump 5 can thereby also be turned off, with it being possible to prevent back-flow and circulation of coolant by the closed control
slide valve 31. As an alternative, the pump 5 is controlled such that the control slide valve 31 prevents coolant circulation.

[0171] It is possible in this manner to quickly reach the operating temperature of the internal combustion engine.

[0172] Furthermore, the low-load condition refers to a powered condition in which the internal combustion engine is operated at low rpm, for example in the idle mode.

[0173] According to the presently discussed embodiment, when the current operating condition of the internal combustion engine is the low-load condition, a flow of coolant through the main coolant pump 3 is interrupted by means of the control slide valve arranged in the main coolant pump and the secondary coolant pump 5 is switched to an ON-mode condition, by means of which the coolant is circulated through the secondary coolant pump 5.

[0174] It is also possible, when the internal combustion engine is running at very low rpm and this possibly causes the circulation performance of the main coolant pump 3 to be insufficient, to additionally switch on the electric secondary coolant pump 5 for what is called electric boosting, in other words to assist coolant circulation based on the pump capacity of the electrically controllable secondary coolant pump 5.

[0175] In the high-load operation of the internal combustion engine, for example on highway driving, etc., the control slide valve 31 of the electrically operated coolant pump 3 is generally moved to its closed position or the pump 3 is shut off and circulation of the coolant is implemented exclusively via the mechanically operated main coolant pump 3.

[0176] If, however, additional cooling capacity is required, the electric coolant pump 5 can be additionally switched on to assist the mechanical coolant pump 3 in conveying the coolant.

[0177] The normal-load condition refers to a powered condition in which the internal combustion engine is preferably operated in the mid-rpm range to apply driving power to the vehicle. Here, the secondary coolant pump 5 is switched to an OFF-mode condition and the control slide valve 31 thereof is generally moved to the closed position, by means of which the coolant in the coolant circuit is circulated through the main coolant pump 3.

[0178] The eco condition refers to a powered condition in which the internal combustion engine is operated normally and the coolant temperature is kept at an elevated level by a control intervention in the cooling system, thus enabling more efficient fuel combustion and hence improved fuel economy.

[0179] When the internal combustion engine is operated in the eco mode (eco condition), operation of the main coolant pump 3 is selectively interrupted by means of an overrunning clutch provided on the pulley 57 of the main coolant pump 3, and/or the control slide valve arranged in the main coolant pump 3 is controlled such that the coolant flow into the main coolant pump 3 is interrupted. In this condition, the coolant is circulated through the secondary coolant pump 5 in order for a desired elevated motor temperature to be obtained.

[0180] The high-rpm condition refers to a powered condition in which the internal combustion engine is operated at high rpm with increased need for cooling, for example on highway driving or the like.

[0181] In accordance with an embodiment according to the method of the invention, when the current operating condition of the internal combustion engine is the high-rpm condition, the coolant flow of the main coolant pump 3 is routed, at least in part, in the bypass mode via the secondary coolant pump 5 to the intake side of the main coolant pump 5 leading to the internal combustion engine.

[0182] The residual heat storing condition, in the end, refers to a powered condition in which the internal combustion engine is switched off and the coolant temperature is supposed to be kept high for as long as possible to reduce the warm-up phase on restarting the internal combustion engine, by means of which the internal combustion engine can be operated sooner in its optimum temperature range.

[0183] In the presently discussed embodiment of the cooling system 1, coolant is prevented from flowing back from the motor to the radiator by shutting off the two pumps 3, 5 by means of the slide valves arranged therein, as a result of which heat exchange between the coolant and the vehicle surroundings can take place only in a greatly delayed manner. The heat generated by the internal combustion engine is thus conserved over a prolonged period when the vehicle is at a standstill and can be used during a subsequent restart to reach the operating temperature more quickly.

[0184] Although the embodiments discussed herein pertain to an electrically operated secondary coolant pump 5 in which the control slide valve 31 is displaced along the drive axle 21 by means of a driving mechanism designed as a threaded spindle, it is also conceivable for the control slide valve to be displaced relative to the impeller, along the drive axle 21, by means of a pneumatically, magnetically and/or hydraulically operated actuator or an electric servomotor rather than via the threaded spindle.

[0185] Although the embodiments discussed herein disclose a control slide valve 31 separately formed on the impeller 25, it is also conceivable for the control slide valve 31 to be integrally formed in the impeller 25. For example, the control slide valve 31 integrally formed in the impeller 25 may be designed such that log-like wall areas having the same effect as the closure member 35 of the control slide valve 31 are formed on the outer surfaces of the impeller 25.

[0186] To control the coolant flow conveyed by a secondary coolant pump 5 thus equipped, an impeller 25 designed in this manner can be displaced along the driving axle 21 such that the log-like wall members projecting towards the back side of the pump casing tightly close the outlet 11 when the impeller 25 thus designed is in a closed position. In an open position of the impeller 25 with the integrally formed control slide valve 31, the wall members are seated in the receptacle 37 formed in the wall of the pump casing 51 so as to be rotatable about the drive shaft 21.

[0187] As an alternative, a control slide valve 31 arranged upstream of the impeller 25 can also be replaced by a rotary slide valve arranged in the pump chamber 53, enclosing the impeller 25 and capable of being rotated to open and closed positions. It is also possible for a sleeve-shaped control slide valve 31 to be arranged downstream of the impeller 25 which is then pushed over the impeller 25 by, for example, the previously discussed threaded spindle drive or a pneumatically, magnetically and/or hydraulically operated actuator or an electric servomotor, and so sealingly closes the outlet 11 of the secondary pump.

[0188] The previously discussed impeller with the control slide valve arranged thereon can also be used as a kind of check-valve in a piping system. Depending on the direction of inflow and on the intake pressure, the slide valve can thereby further convey the inflowing medium on the shaft holding the impeller and the slide valve or, when the flow pressure against
the direction of conveyance is sufficiently high, close the piping system by displacing the control slide valve to its

closed position.

[0189] Although the electric coolant pump 5 discussed herein comprises an electric motor 7 having a power output
between 20 W and 100 W, a more powerful electric motor having, for example, up to 2 kW can also be employed such
that the electric coolant pump can, if need be, also handle coolant circulation as the only pump in the cooling circuit.

[0190] The present invention relates to a controllable cooling system 1 for a vehicle, comprising a coolant circuit which
routes coolant to and out of an internal combustion engine, and to a mechanically operated, controllable main coolant
pump 3 and an electrically operated, controllable secondary coolant pump 5.

[0191] The cooling system further comprises a control device which controls the main coolant pump 3 and the secon-
dary coolant pump 5 in dependence on operating conditions of the internal combustion engine. The invention more-
over provides an electrically operated, controllable secondary coolant pump 5 for such a cooling system 1, an impeller for
use in this secondary coolant pump 5, and a method for controlling the coolant flow in such a cooling system 1.

1. A controllable cooling system for a motor vehicle, comprising:
a coolant circuit for supplying and discharging coolant to
and from an internal combustion engine of the vehicle;
a mechanically operated, controllable main coolant pump
comprising an inlet for supplying the coolant into the
main coolant pump and an outlet for discharging the
coolant to the internal combustion engine, and
an electrically operated, controllable secondary coolant
pump comprising an inlet for supplying the coolant into the
secondary coolant pump and an outlet for discharging
a coolant, conveyed as a bypass coolant flow, towards the main coolant pump,
wherein the secondary coolant pump is arranged upstream
of the main coolant pump in the direction of flow, fork-
ing off from a coolant line leading to the main coolant
pump in the direction of coolant flow,
the coolant conveyed by means of the secondary coolant
pump is supplied, downstream of the main coolant pump
and without flowing through the main coolant pump,
into the outlet leading to the internal combustion engine,
the secondary coolant pump comprises a pump casing with
a pump chamber formed therein, wherein on a section of
the pump casing an electric motor is arranged which
provides driving power for the secondary coolant pump
by means of a drive shaft extending into the pump cham-
ber,
the secondary coolant pump in the pump chamber com-
prises an impeller serving as a conveyor member which
is coaxially arranged on the drive shaft and drivably
connected thereto, and
the secondary coolant pump comprises a control slide
valve formed on the impeller which can be moved at
least to open and closed positions, for controlling the
bypass coolant flow conveyed by the secondary coolant
pump, particularly for preventing back-flow of the cool-
ant in a direction opposite to the conveying direction of
the secondary coolant pump.

2. The system according to claim 1, wherein the main
coolant pump comprises a pump casing with a pump chamber
formed therein, wherein an impeller serving as a conveyor
member is arranged in the pump chamber and is driven via a
shaft extending into the pump chamber which is preferably
driven by a belt drive.

3. The system according to claim 1, wherein the main
coolant pump further comprises a control slide valve formed
on the impeller and arranged coaxially thereto which can be
moved at least to open and closed positions, preferably along
the impeller mounted in the pump chamber, for controlling
the coolant flow conveyed by the main coolant pump.

4. The system according to claim 1, wherein the electric
motor of the secondary coolant pump is designed as a dry
rotor or wet rotor.

5. The system according to claim 1, further comprising a
control device which controls the main coolant pump and/or
the secondary coolant pump in dependence on assigned oper-
ating conditions of the internal combustion engine.

6. An electric coolant pump for use in a cooling system
according to claim 1, wherein the electric coolant pump is
designed as a radial flow pump and comprises:
a pump casing;
a preferably flange-like inlet and a preferably flange-like
outlet;
a pump chamber formed in the pump casing, wherein a
pump wheel is arranged on a pump shaft in the pump
chamber, the pump wheel being drivable by an electric
motor through the intermediary of the pump shaft, and
a slide valve that is displaceable at least to open and closed
positions, for controlling a bypass coolant flow con-
veyed by the coolant pump, particularly for preventing
back-flow of the coolant in a direction opposite to the
conveying direction of the secondary coolant pump,
wherein the coolant to be conveyed, diverted from a cool-
ant line, can be introduced into the pump chamber
formed in the pump casing through the substantially
conically extending inlet, and the coolant introduced
into the pump chamber can be discharged from the pump
chamber through the outlet arranged substantially at a
right angle radially to the inlet line;
wherein the impeller arranged in the pump chamber and
designed as a radial flow pump impeller sucks the cool-
ant in through rotational movement in an axial direction
and conveys it into the outlet in a radial direction;
the slide valve is designed as a control slide valve arranged
 coaxially to the pump shaft on the impeller; and
the electric motor is preferably arranged on a section of
the pump casing facing away from the inlet;
wherein the electric motor comprises a drive shaft protrud-
ing into the pump chamber,
the impeller and the control slide valve are coaxially
arranged on the drive shaft and are retained on the drive
shaft in a positive fit manner, preferably by means of
retaining members, and
the control slide valve is cylindrically designed, enclosing
the impeller, and is displaceable in an axial direction of
the impeller to open and closed positions.

7. The coolant pump according to claim 6, wherein the
control slide valve is connected to the impeller such that
blades of the impeller penetrate the control slide valve.

8. The coolant pump according to claim 6, wherein the
electric motor is designed as a dry rotor and is sealed from
the pump chamber by means of a shaft seal arranged on the drive
shaft.
9. The coolant pump according to claim 6, wherein the electric motor (7) is designed as a wet rotor and is cooled by the coolant conveyed by the coolant pump.

10. The coolant pump according to claim 6, wherein the control slide valve is displaceable along the drive shaft by means of at least one actuator arranged in the coolant pump, wherein the actuator is designed as a pneumatically, magnetically and/or hydraulically actuated slide valve or as an electric servomotor.

11. The coolant pump according to claim 6, wherein the control slide valve comprises a section enclosing the drive shaft and facing towards the inlet, with a threaded section formed on its inner circumference.

12. The coolant pump according to claim 11, wherein a threaded section complementary to the threaded section of the control slide valve is formed on a section of the drive shaft facing away from the electric motor, and the control slide valve is displaceable along the drive shaft by mutual engagement of the threaded sections.

13. The coolant pump according to claim 6, wherein the control slide valve is designed to follow the contour of the front side of the impeller and has arranged at its outer end a radially continuous closure member, wherein a first sealing member, arranged radially outside the control slide valve, is disposed at an end of the closure member facing away from the electric motor.

14. The coolant pump according to claim 13, wherein a receptacle into which the closure member of the control slide valve can be introduced in the open position thereof is formed in the pump chamber.

15. The coolant pump according to claim 13, wherein a second sealing member, arranged radially inside the control slide valve, is disposed at a radially outer end of the impeller facing towards the electric motor.

16. The coolant pump according to claim 15, wherein the diameter of the first sealing member is larger than the diameter of the second sealing member.

17. The coolant pump according to claim 15, wherein the outlet can be tightly closed, via the closure member, the first sealing member and the second sealing member, by the control slide valve in the closed position thereof.

18. The coolant pump according to claim 6, wherein a braking member is further provided, by means of which the impeller can be secured to an inner wall of the pump casing.

19. The coolant pump according to claim 18, wherein the braking member is formed on the impeller and preferably consists of a pretensioned braking spring or plate-like brake disc which preferably comprises at its radially outer ends, in a radially inward direction, substantially wedge-tapered thickenings, wherein the braking member is brought into frictional engagement with the inner wall of the pump casing adjoining the electric motor, preferably by means of the thickenings, to secure the impeller to the pump casing.

20. The coolant pump according to claim 18, wherein the braking member, including in particular, the thickenings thereof, is designed to disconnect from the inner wall of the pump casing as the speed of rotation of the impeller caused by the drive shaft of the electric motor increases, so as to disengage the impeller.

21. An impeller for use in a coolant pump according to claim 6 for a cooling system according to claim 1, said impeller comprising:

a plurality of blades that are preferably typical of radial flow pumps and formed on the impeller surface facing towards a coolant inlet; a recess for receiving a drive shaft; a control slide valve connected to the impeller; and a braking member arranged on the impeller.

22. The impeller according to claim 21, wherein the control slide valve comprises at its front end a first sealing member arranged radially outside thereof and the impeller comprises at its radially outer end a second sealing member arranged radially inside the control slide valve.

23. The impeller according to claim 21, wherein the control slide valve is integrally formed with the impeller such that the blades of the impeller penetrate the control slide valve in an axial direction.

24. The impeller according to claim 21, wherein the braking member is formed on a back side surface of the impeller.

25. The impeller according to claim 21, wherein the braking member consists of a pretensioned braking spring or plate-like brake disc capable of being brought into frictional engagement with a surface opposite the back side surface of the impeller, to secure the impeller to this surface.

26. The impeller according to claim 21, wherein the braking member is designed such that its braking effect decreases as the speed of rotation of the impeller increases, whereby it approaches the back side surface of the impeller to disengage the impeller.

27. The impeller according to claim 21, wherein the control slide valve is designed to follow the contour of the impeller and comprises at its outer end a radially continuous closure member.

28. The impeller according to claims 21, wherein the control slide valve comprises in its frontal area a hollow, compartment-like section with a threaded section formed on the inner circumferential wall thereof.

29. A method for controlling a coolant flow in a cooling system of a motor vehicle according to claim 1, wherein the cooling system comprises a controllable main coolant pump mechanically operated by the driving force of an internal combustion engine arranged in the vehicle and a controllable secondary coolant pump electrically operated by a separately arranged electric motor, said method comprising the steps of:
detecting a current operating condition of an internal combustion engine of the vehicle;
detecting a coolant temperature of a coolant circulating in a coolant circuit of the vehicle;
reading out control parameters from a cooling circuit map; controlling the main coolant pump and the secondary coolant pump based upon the control parameters read out from the cooling circuit map; and controlling the coolant flow by selectively switching the main coolant pump and/or the secondary coolant pump.

30. The method according to claim 29, wherein the current operating condition of the internal combustion engine includes a start-stop condition, a warm-up condition, a low-load condition, a normal-load condition, an eco condition, a high-rpm condition, and a residual heat storing condition.

31. The method according to claim 29, wherein the control parameters in the cooling circuit map include at least a desired coolant temperature, and/or a desired motor temperature and/or a desired coolant flow rate, and/or the like.

32. The method according to claim 30, wherein, when the current operating condition of the internal combustion engine is the warm-up condition, the secondary coolant pump is
switched to an OFF-mode condition and a coolant flow through the main coolant pump is interrupted by means of a control slide valve arranged in the main coolant pump, such that circulation of the coolant is interrupted.

33. The method according to claim 30, wherein, the current operating condition of the internal combustion engine is the start-stop condition in which the main coolant pump is temporarily unpowered during a stop phase of the internal combustion engine, the secondary coolant pump is switched to an ON-mode condition, by means of which the coolant is circulated through the secondary coolant pump.

34. The method according to claim 30, wherein, when the current operating condition of the internal combustion engine is the low-load condition, a coolant flow through the main coolant pump is interrupted by means of a control slide valve arranged in the main coolant pump and the secondary coolant pump is switched to an ON-mode condition, by means of which the coolant is circulated through the secondary coolant pump.

35. The method according to claim 30, wherein, when the current operating condition of the internal combustion engine is the normal-load condition, the secondary coolant pump is switched to an OFF-mode condition and the control slide valve thereof is closed, by means of which the coolant in the coolant circuit is circulated through the main coolant pump.

36. The method according to claim 30, wherein, when the current operating condition of the internal combustion engine is the eco condition, operation of the main coolant pump is selectively interrupted by means of an overrunning clutch provided on the belt drive system of the main coolant pump, or a control slide valve arranged in the main coolant pump is controlled such that the coolant flow in the main coolant pump is interrupted and the coolant is circulated through the secondary coolant pump in order for a desired elevated motor temperature to be obtained.

37. The method according to claim 30, wherein, when the current operating condition of the internal combustion engine is the high-rpm condition, the coolant flow of the main coolant pump is routed, at least in part, in the bypass mode via the secondary coolant pump to the intake side of the main coolant pump.

38. The method according to claim 30, wherein, when the current operating state of the internal combustion engine is the residual heat storing condition with the internal combustion engine at a standstill, both the control slide valve of the main coolant pump and the control slide valve of the secondary coolant pump are closed in order to prevent circulation of the coolant in the cooling circuit.

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