

Description

[0001] The invention relates to a household appliance comprising a heater and a heat pump including a compressor. The invention relates to a method for operating a compressor of a household appliance. The invention is particularly useful for clothes drying appliances, in particular clothes drying appliances having an ECO mode and a SPEED mode.

[0002] Clothes drying appliances comprising a heat pump having a compressor are generally known in the art.

[0003] For example, WO 2007/077084 A1 discloses a domestic appliance for the care of washed articles, in particular a tumble drier. Said appliance comprises a container for receiving the washed articles, a process air supply that is connected to the container, allowing process air to flow through the container, and a first heat exchanger which is coupled to the process air supply and is designed to dehumidify the process air that exits the container.

[0004] EP 2 985 466 A1 discloses a rotary compressor which comprises a cylindrical housing, a cylindrical roller accommodated in the housing, a motor shaft leading through the roller having a cam for rolling the roller along a side wall of the housing, and a discharge port leading through a bottom cover. A household appliance, in particular laundry care apparatus, comprises the heat pump.

[0005] At a start of a drying program, the components of the heat pump as well as the refrigerant are often at ambient temperature. During a first phase of the drying program, the heat pump is gradually heating up. Only when a condensing temperature at a condenser of the heat pump has risen high enough, a high dehumidifying capacity is achieved. This heating-up time can stretch from 20 to 50 minutes, depending on the heat pump dryer appliance, the ambient temperature etc.

[0006] It is the **object** of the present invention to at least partially overcome the problems associated with the prior art. It is a particular object of the present invention to increase a dehumidifying efficiency of a household appliance comprising a heat pump and/or to reduce a drying time.

[0007] The object is achieved according to the features of the independent claims. Advantageous embodiments can be found, e.g., in the dependent claims and/or in the description.

[0008] The object is achieved by a household appliance comprising a heater and a heat pump including a compressor, wherein the heater is adapted to heat the compressor.

[0009] This gives the advantage that a high dehumidifying efficiency of the household appliance can be achieved considerably faster. This, in turn allows to achieve a shorter drying time. In particular, a stable condition of the refrigerant flowing in the cooling circuit can be achieved much faster. Particularly, an initial start phase of the heat pump during which the cooling circuit

is brought to its stable condition may be shortened up to one half, e.g. from 20 to 50 min to 10 to 25 min (50% reduction). Thus, depending on the clothes / laundry load and the heater configuration, a reduction in drying time of up to 1 to 3,5 min/kg may be achieved.

[0010] The improved dehumidifying effect can be based on that, in the compressor, the time needed for solubilisation of the refrigerant into oil is significantly reduced with higher temperatures. Thus, the desired quantity of refrigerant in heat exchangers (condenser and evaporator) corresponding to a stable condition of the refrigerant in the cooling circuit is reached earlier than before.

[0011] That the heater is adapted to heat the compressor includes that this heater's function is primarily or exclusively to heat or to warm up the compressor. Such a heater can also be regarded as a heater that is dedicated to heat the compressor ("dedicated") heater. In particular, other heaters that are not primarily used to warm up the compressor are not regarded to be such dedicated heaters.

[0012] The heat pump may comprise the compressor, a condenser, an expansion means (e.g. a capillary or an expansion valve), and an evaporator, connected in this order by the fluid conduits carrying refrigerant. Thus, the heat pump provides a cooling circuit for the refrigerant flowing through the compressor, the condenser, the expansion means, and the evaporator, in this direction. The fluid conduits may be or comprise pipes etc. The pipes may be made of copper, aluminium etc. The condenser and the evaporator may act as heat exchangers. The refrigerant may, for instance, comprise R290, R1270, R32, R134a, R407C, etc.

[0013] The compressor may be a BLDC-driven compressor, i.e., a compressor having a BLDC motor. Alternatively, the compressor is an AC rotary compressor, i.e., a compressor having an AC motor. An AC-driven rotary compressor may have a fixed nominal speed. While BLDC-driven compressors have a higher efficiency than AC rotary compressors, they are also more expensive and need additional components like an inverter electronic to be operated.

[0014] Advantageously, the housing is made of metal to achieve a high thermal conductivity.

[0015] Generally, the type and set-up of such a (dedicated) heater is not limited. For example, the heater may be a non-contact heater positioned in some distance from the compressor. Such a non-contact heater may comprise one or more radiation heat sources like an electrical resistance heater, an IR-lamp, a halogen lamp, etc. It is an advantageous embodiment that the heater is an electric resistance heater.

[0016] It is an embodiment that the heater is attached to the compressor. This advantageously gives a particularly effective heat transfer from the heater to the compressor by thermal conduction via contact areas. Particularly in this case, it is an advantageous embodiment that the heater is an electric resistance heater. Generally, it

is an advantage if the attachment achieves a proper contact between the heater and the compressor housing, e.g., a continuous contact having a low thermal resistance.

[0017] It is an embodiment that the heater is attached to a housing of the compressor. This gives the advantage that the heater may be attached in a particularly simple manner. Also, in such a way, the compressor may be advantageously heated over a large area. Generally, the heater may be arranged to effectively heat the whole housing or only part of the housing. The housing may also be called a compressor shell. The attachment may be realized by any suitable means, e.g. gluing, clipping, screwing etc.

[0018] It is a variant that the heater is attached to an outer side of the housing. This further simplifies attachment of the heater.

[0019] It is an embodiment that the electric resistance heater comprises at least one electrically conducting heating band or electric cable wound around the housing. This allows a particularly simple and robust heater arrangement to heat a large surface of the housing with a high heating power.

[0020] It is an embodiment that the household appliance further comprises a control unit adapted to control a heating power of the heater, e.g. to switch the heater on and off. This gives the advantage that the operation of the heater may be precisely controlled. For example, by using the control unit, the operation of the heater may be coordinated with a central control unit of the household appliance. This gives the advantage that the heater may be operated in conjunction with a drying program. The heater control unit may be integrated in or connected with the central control unit. The control unit may comprise at least one processor.

[0021] The heating power of an electric heater may be controlled or set by setting a respective electric power, in particular, a respective electric current, running through the electric heater.

[0022] It is an embodiment that the control unit is connected to at least one temperature sensor. This advantageously allows the control unit to adapt the operation of the heater based on temperatures measured by the temperature sensor.

[0023] It is an embodiment that the control unit is adapted to operate the heater until at least one predefined target temperature for the at least one temperature sensor is reached. This gives the advantage that operation of the heater may be adapted for effectively reaching the stable condition while achieving a low energy consumption of the heater. The target temperature may be associated with a stable condition. In a first variant, the heater is only operated until the stable condition is reached. In a second variant, the control unit is adapted to monitor the at least one temperature sensor and to operate the heater each time, the temperature falls under a predetermined (lower) temperature threshold. The lower temperature threshold is lower than the target temperature.

[0024] In one variant, the control unit is adapted to switch on a heating power of the heater when the compressor is switched on. In another variant, the control unit is adapted to switch on a heating power before the compressor is switched on and/or after the compressor has been switched off.

[0025] In one variant, the control unit is adapted to adjust a level of a heating power of the heater. This allows an effective and precise way to heat up the compressor, in particular to avoid a thermal overshoot. The adjustment of the level of the heating power may be time-dependent, in particular only time-controlled, e.g. based on a duration of activation of the heater. This, in turn, saves energy for operating the heater.

[0026] It is an embodiment that the control unit is connected to a temperature sensor and is adapted to adjust a level of a heating power according to a temperature measured by the temperature sensor. This allows a particularly effective and precise way to heat up the compressor, in particular to avoid a thermal overshoot. Adjusting the level of the heating power may include setting the level of the heating power to one or more levels larger than zero. The levels may include several distinct levels or steps. Alternatively, the control unit is adapted to continuously or quasi-continuously adjust the level of the heating power. Adjusting the level of the heating power may include setting the level of the heating power to zero.

[0027] In a first variant, adjusting the level of the heating power may be achieved by varying a resistance value of a series resistor or dropping resistor, thus, e.g., leading to a variation of an electric current flowing through the heater. In a second variant, this may be achieved by repeatedly switching the heater on and off (PWM-like heating); in this case, the electric current running through the electric heater may be constant in the switched-on state (during a pulse). The width of the pulses, their period, and/or their duty cycle may be varied by the control unit. Generally, the control unit may be or may comprise a PID (proportional-integral-derivative) controller to imprint the electric power.

[0028] In one variant, the at least one temperature, e.g. a target temperature and/or a temperature measured by the at least one temperature sensor, may be any temperature associated with the cooling circuit.

[0029] It is an embodiment that the at least one target temperature is at a least one temperature out of the group comprising

- a temperature of the compressor, in particular of a compressor discharge temperature;
- a temperature of the condenser, in particular of a refrigerant output of the condenser ("condenser out temperature");
- an ambient temperature, e.g. within and/or outside the household appliance;
- a temperature in the process air channel (e.g., before the evaporator 6, before or after the condenser 9

etc.).

[0030] The household appliance may comprise respective temperature sensors. Additionally or alternatively, the temperatures may be derived from other measurements.

[0031] It is an embodiment that the target temperature is a temperature measured at the compressor, in particular at the housing of at a surface of the compressor.

[0032] It is an embodiment that the target temperature is a temperature of the refrigerant, e.g. measured at a suitable point of the cooling circuit, e.g. at a discharge port of the compressor and/or at a refrigerant output of the condenser.

[0033] In the above cases, the target temperature may correspond to an upper temperature threshold. Then, the control unit may be adapted to operate the heater until the at least one target temperature is reached or exceeded.

[0034] It is an embodiment, that the control unit is connected to a temperature sensor for sensing the ambient temperature. Then, it may be a variant that the control unit is adapted to switch on or activate the heater when the ambient temperature is below a predefined ambient temperature, in particular irrespective of an activation of the compressor, e.g. when the household appliance is at a place having a very cold ambient temperature. This gives the advantage that the compressor may be protected against slugging (i.e., liquid refrigerant is directly entering the compressor) that could produce lubrication oil layers washing which in turn, may lead to blockage of the compressor.

[0035] It is an embodiment that the control unit is adapted to gradually reduce the heating power over time compared to a highest heating power at the beginning of an operation or activation of the heater. This advantageously allows heating up the compressor in a particularly energy efficient manner by mitigating or avoiding a thermal overshoot. The reduction of the heating power may, e.g., be achieved by using a proportional control or a PID control.

[0036] It is an embodiment that the household appliance is a clothes drying appliance. The clothes drying appliance may be a clothes dryer or a washing machine / clothes dryer combination. The clothes drying appliance may be a domestic or household appliance.

[0037] In case of a clothes drying appliance, the condenser and the evaporator may act as heat exchangers positioned in a process air channel (e.g. an open-loop or closed-loop process air channel). Particularly, the condenser may act as a heater for process air flowing through the process air channel while the evaporator may act as a cooling device to cool down the process air. The arrangement and working principle of heat pumps for a clothes drying apparatus is generally known and will thus not be described in greater detail.

[0038] The above described invention is particularly effective for a household appliance in which the amount of

refrigerant is 200 g or less, in particular 160 g or less, in particular 150 g or less, in particular 140 g or less, in particular 120 g or less, in particular 100 g or less. This is the case, e.g., in clothes drying appliances. The above described invention advantageously allows reducing the amount of refrigerant.

[0039] It is an embodiment that, in a first mode of operation (e.g. called an "ECO mode") of the household appliance, the household appliance is adapted to permanently turn off the heater and, in a second mode of operation (e.g. called an "SPEED mode"), the household appliance is adapted to turn on the heater.

[0040] The object is also achieved by a method for operating a compressor of a household appliance comprising a heat pump including a compressor, wherein the compressor is heated by a heater. The method may be embodied in analogy to the household appliance and achieves the same advantages.

[0041] For example, it is an embodiment the heater is operated until at least one target temperature is reached.

[0042] It is an embodiment that a heating power is adjusted according to at least one temperature measured by the at least one temperature sensor.

[0043] It is an embodiment that the at least one temperature is at a least one temperature out of the group comprising:

- a temperature of the compressor, in particular of a compressor discharge temperature;
- a temperature of the condenser, in particular of a refrigerant output of the condenser;
- an ambient temperature;
- at least one temperature of process air or a process air channel.

[0044] It is an embodiment that the heater is switch on when the ambient temperature is below a predefined ambient temperature.

[0045] It is an embodiment that the heating power is gradually reduced over time compared to a highest heating power at the beginning of an operation of the heater.

[0046] The above described features and advantages of the invention as well as their kind of implementation will now be schematically described in more detail by at least one embodiment in the context of one or more figures.

[0047] Fig.1 shows a functional block diagram of a clothes drying apparatus 1 according to the invention.

[0048] The clothes drying apparatus 1 has a closed-loop process air circuit 2 comprising a rotational drum 3 for holding clothes. An output port of the drum 3 is connected to a lint filter 4 via a section of a process air channel 5 (long dashed lines). The lint filter 4 is connected to a first heat exchanger 6 via another section of the process air channel 5. Process air P is guided over a surface of the first heat exchanger 6 where it is cooled down so that the moist process air P from the drum 3 condensates. The resulting condensate 7 may be collected in a tray 8.

The collected condensate may be lead to waste or may be re-used, e.g. for cleaning at least the first heat exchanger 6. The heat exchanger 6 is further connected to a second heat exchanger 9 via yet another section of the process air channel 5. At the second heat exchanger 9, the drier process air P coming from the first heat exchanger 6 is heated up. The second heat exchanger 9 is connected to a fan 10 for moving the process air P within the process air circuit 2 via yet another section of the process air channel 5. The fan 10 is connected to an inlet port of the drum 3 via yet another section of the process air channel 5. Thus, dry and warm process air P is introduced into the drum 3 to dry the clothes. The fan 10 may also be placed at another position within the process air circuit 2, e.g. between the drum 3 and the lint filter 4. The process air circuit 2 may have additional components (not shown) like an additional electric heater, an additional fan, further lint filters etc.

[0049] The first heat exchanger 6 and the second heat exchanger 9 are also components of a heat pump 11 of the clothes drying apparatus 1. The first heat exchanger 6 corresponds to an evaporator of the heat pump 11 while the second heat exchanger 9 corresponds to its condenser. The heat pump 11 further comprises an AC rotary compressor 12 and an expansion means 13, e.g. a capillary or an expansion valve.

[0050] A high-pressure side or port of the AC rotary compressor 12 is connected to the condenser (second heat exchanger 9) via a first fluid conduit 14 for refrigerant F. The condenser 9 is further connected to a high-pressure side of the expansion means 13 via a second fluid conduit 15 for the refrigerant F. A low-pressure side of the expansion means 13 is connected to the evaporator (first heat exchanger 6) via a third fluid conduit 16 for the refrigerant F. The evaporator 6 is connected to a low-pressure side of the AC rotary compressor 12 via a fourth fluid conduit 17 for the refrigerant F. The amount of refrigerant may be 200 g or less, in particular 160 g or less, in particular 150 g or less, in particular 140 g or less, in particular 120 g or less, in particular 100 g or less.

[0051] When the AC rotary compressor 12 is switched on, pressurized refrigerant F flows from the high-pressure side of the AC rotary compressor 12, through the first conduit 14, through the condenser 9, through the second conduit 15, through the expansion means 13 (where it is expanded at its low-pressure side), through the third conduit 16, through the evaporator 6, and through the fourth conduit 17 to the low-pressure side of the AC rotary compressor 12. In the AC rotary compressor 12, the refrigerant F is compressed and is then again emitted at the high-pressure side of the AC rotary compressor 12.

[0052] When the AC rotary compressor 12 is switched off, the refrigerant F is not moved by the AC rotary compressor 12 anymore but may - if not prevented - move to equilibrate pressure between the high-pressure section of the heat pump 11 and the low-pressure section of the heat pump 11.

[0053] The AC rotary compressor 12 comprises a housing 18 or shell. At the outside of the housing 18 is attached an electrical resistance heater 19 comprising at least one electrically conducting heating band or heating cable 20 wound around the housing 18. The heater 19 is adapted to heat the housing 18 and thus the functional components of the AC rotary compressor 12 housed by the housing 18. Heating or activation of the heater 19 is achieved by sending an electric current through the at least one heating band or heating cable 20. To this effect, the heater 19 may be connected to a current supply (not shown), e.g. via one or more switches (not shown).

[0054] The clothes drying apparatus 1 also comprises a control unit 21 controlling operation functional components of the clothes drying apparatus 1, e.g. the AC rotary compressor 12, the heater 19, the drum 3 and the fan 10, as well as further functional components. In particular, the control unit 21 is adapted to control a heating power of the heater 19. Controlling the heating power may include switching the heater 19 on and off and adjusting the power level in a switched-on state of the heater 19.

[0055] The control unit 21 is further connected to one or more of the following temperature sensors:

- a temperature sensor 22 for measuring a temperature of the AC rotary compressor 12, in particular at its discharge pipe / connection ("compressor discharge temperature");
- a temperature sensor 24 for measuring a temperature of the condenser 9, in particular at a refrigerant output 25 of the condenser 9 ("condenser out temperature");
- a temperature sensor 26 for measuring an ambient temperature, e.g. within and/or outside the household appliance 1.
- at least one other temperature sensor, e.g. for measuring a temperature in the process air channel 5 (e.g., before the evaporator 6, before or after the condenser 9 etc.)

[0056] Thus, the control unit 21 may operate the heater 19 based on the temperature measured by one or more of the above temperature sensors 22, 24, 26. In particular, the control unit 21 may be adapted to operate the heater 19 until at least one target temperature corresponding to the compressor discharge temperature and/or corresponding to the condenser out temperature is reached. For instance, the control unit 21 may switch of the heater 19 if a target temperature of the compressor discharge temperature is reached and/or if a target temperature of the condenser out temperature is reached. Also, the control unit 21 may be adapted to adjust a heating power of the heater 19 based on the compressor discharge temperature, the condenser out temperature and/or the ambient temperature.

[0057] The control unit 21 may further be adapted to

switch on the heater 19 - if necessary - when the AC rotary compressor 12 is switched on. An activation of the heater 19 may not be necessary if the at least one target temperature has already been reached.

[0058] In one variant, the control unit 21 may further be adapted to switch on the heater 19 if the at least one target temperature has not been reached even if the AC rotary compressor 12 is switched off, e.g., at a beginning of a drying program.

[0059] The control unit 21 may also be adapted to switch on the heater 19 when the ambient temperature is below a predefined ambient temperature. A level of the heating power for such a case may be relatively low, especially if the at least one target temperature has already been reached. This is advantageous if the ambient temperature is very low.

[0060] The control unit 21 may also be adapted to gradually reduce the heating power over time, especially compared to a highest heating power at the beginning of an operation of the heater 19.

[0061] Of course, the invention is not restricted to the described embodiments.

[0062] For example, the clothes drying apparatus 1 may have no lint filter 4.

[0063] Also, the clothes drying apparatus 1 may comprise an additional fan for cooling the AC rotary compressor 12.

[0064] Further, a BDLC-driven compressor may be used.

List of Reference Signs

[0065]

1	Clothes drying apparatus
2	Process air circuit
3	Drum
4	Lint filter
5	Process air channel
6	First heat exchanger / evaporator
7	Condensate
8	Tray
9	Second heat exchanger / condenser
10	Fan
11	Heat pump
12	AC rotary compressor
13	Expansion means
14	First conduit
15	Second conduit
16	Third conduit
17	Fourth conduit
18	Housing
19	Heater
20	Heating band or heating cable
21	Control unit
22	Temperature sensor
23	Discharge port of the compressor
24	Temperature sensor

25	Refrigerant output of the condenser
26	Temperature sensor
F	Refrigerant
P	Process air

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Claims

1. A household appliance (1) comprising a heater (19) and a heat pump (11) including a compressor (12), wherein the heater (19) is adapted to heat the compressor (12).
2. The household appliance (1) according to claim 1, wherein the heater (19) is attached to the compressor (12).
3. The household appliance (1) according to claim 2, wherein the heater (19) is attached to a housing (18) of the compressor (12).
4. The household appliance (1) according to any of the preceding claims, wherein the heater (19) is an electric resistance heater (19).
5. The household appliance (1) according to claims 3 and 4, wherein the electric resistance heater (19) comprises at least one electrically conducting heating band or heating cable (20) wound around the housing (18).
6. The household appliance (1) according to any of the preceding claims, further comprising a control unit (21) adapted to control a heating power of the heater (19).
7. The household appliance (1) according to claim 6, wherein the control unit (21) is connected to at least one temperature sensor (22, 24, 26) and is adapted to operate the heater (19) until at least one target temperature is reached.
8. The household appliance (1) according to claim 7, wherein the control unit (21) is adapted to adjust a heating power according to at least one temperature measured by the at least one temperature sensor (22, 24, 26).
9. The household appliance (1) according to any of claims 7 and 8, wherein the at least one temperature is at a least one temperature out of the group comprising:
 - a temperature of the compressor (12), in particular of a compressor discharge temperature;
 - a temperature of a condenser (9), in particular of a refrigerant output (25) of the condenser (9);
 - an ambient temperature;

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- at least one temperature of process air (P) or a process air channel (5).

10. The household appliance (1) according to claim 9, wherein the control unit (21) is connected to a temperature sensor (26) for sensing the ambient temperature within or outside the household appliance (1) and the control unit (21) is adapted to switch on the heater (19) when the ambient temperature is below a predefined ambient temperature. 5
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11. The household appliance (1) according to any of claims 6 to 10, wherein the control unit (21) is adapted to gradually reduce the heating power over time compared to a highest heating power at the beginning of an operation of the heater (19). 15
12. The household appliance (1) according to any of the preceding claims, wherein an amount of a refrigerant (F) is 200 g or less, in particular 160 g or less, in particular 150 g or less, in particular 140 g or less, in particular 120 g or less, in particular 100 g or less. 20
13. The household appliance (1) according to any of the preceding claims, wherein the household appliance (1) is a clothes drying appliance. 25
14. The household appliance (1) according to any of the preceding claims, wherein, in a first mode of operation (e.g. called an "ECO mode") of the household appliance (1), the household appliance (1) is adapted to permanently turn off the heater (19) and, in a second mode of operation (e.g. called an "SPEED mode"), the household appliance (1) is adapted to turn on the heater (19). 30
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15. A method for operating a compressor (12) of a household appliance (1) comprising a heat pump (11) including a compressor (12), wherein the compressor (12) is heated by a heater (19). 40

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EUROPEAN SEARCH REPORT

Application Number
EP 19 15 7626

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