A dishwasher and a method for controlling a drying time in the dishwasher. The dishwasher may comprise a washing compartment for receiving items to be washed, wherein the items to be washed are heated to a defined initial temperature which is above the temperature of a condensation surface communicating with the washing compartment. The method of the invention may include detecting a temperature gradient of a characteristic temperature during the drying of the items to be cleaned, and using the temperature gradient of the characteristic temperature to detect a property that is characteristic of the degree of evaporation of water on the surface of the items to be cleaned.
METHOD FOR THE DRYING TIME CONTROL IN DISHWASHERS

[0001] The invention relates to a method as claimed in the preamble of claim 1.
[0002] For an automatic dishwasher the energy consumption required for the various operations and the time required for these are important performance parameters, which are not independent but closely linked, to some extent even conversely in that one is minimized at the cost of the other. In the last operation the washed dishes are generally dried in the washing compartment in a drying operation. Various methods and principles are known for this.
[0003] In the case of a method type based on inherent heat drying a heating facility supplies heat to the interior space of the washing compartment but the moisture is not conducted away. The temperature of the interior air of the washing compartment rises in this process, with the result that it can take on an increased relative air humidity. A cold surface enhances the drying performance. The moisture from the interior air can condense on it, thereby maintaining or increasing the capacity of the interior air to absorb moisture.
[0004] Conventional dishwashers with inherent heat drying supply a predetermined quantity of (thermal) energy to the washing compartment regardless of the load, i.e. the quantity and thermal capacity of the dishes to be dried. A predetermined fixed time period is provided for the drying operation. The quantity of heat and the time period are measured so that an adequate drying result is achieved even for a large load. This method does not take a small load into account. Also moisture sensors cannot be used with inherent air drying, as the degree of moisture in the washing compartment during drying is always saturated, probably even over-saturated.
[0005] The object of the present invention is to optimize the drying operation in a dishwasher. It should be possible to achieve optimized drying economically and in a technically simple manner; in particular it should be possible without technically complex sensors and/or without apparatus that is required specifically for drying.
[0006] The invention is based on a method for regulating a drying period in a dishwasher having a washing compartment for receiving items to be washed, the items to be washed being heated to a predetermined initial temperature (T₀), which is above the temperature of a condensation surface communicating with the washing compartment.
[0007] The object of the invention is achieved by the following steps:
(a) detecting a temperature gradient of a characteristic temperature (T) during the drying of the items to be washed,
(b) using the temperature gradient of the characteristic temperature to detect a feature that is characteristic of the degree of evaporation of water from the surface of the items to be washed (28a, 28b).
[0008] The feature characteristic of achieving the complete drying of the items to be washed can be the reaching of or being above or below an appropriately selected critical value that is characteristic of complete drying, i.e. a threshold of the characteristic temperature (T). Identification of the characteristic feature can include identification of the reaching of an end temperature or the start of an asymptotic behavior of the time dependency of the characteristic temperature. It is thus possible to identify that complete drying has been achieved and to terminate the drying operation prematurely, i.e. for example before the end of a programmed drying period, thereby saving time.
[0009] The characteristic feature can also be the reaching of a value of the temporal derivation of the characteristic temperature that is characteristic of complete drying, i.e. a threshold for d(T)/dt. It can also be the reaching of a characteristic value of a temperature difference (ΔT=11-12) or the temporal derivation of the temperature difference (d(ΔT)/dt) between two temperatures T1 and T2 measured at two different positions, i.e. a threshold for ΔT or for d(ΔT)/dt. The temporal derivation of the temperature signals can be calculated and supplied for evaluation by software processed in a processor of a central control unit.
[0010] The detection of such characteristic features of the characteristic temperature allows automatic drying identification. By selecting the characteristic temperature and the characteristic features appropriately it is possible for automatic drying identification to be independent or largely independent of the (heat and noise) insulation of the washing compartment, ambient conditions such as the ambient temperature (e.g. in summer and winter) and the specific installation situation of the automatic dishwasher (e.g. freestanding or built into a kitchen unit between adjacent cabinets on the right and left).
[0011] The method has the advantage that the drying operation can be controlled as a function of load. With a small load it is therefore possible to save energy and with a larger load an adequate drying result can still be achieved. Optimization is generally a matter of terminating the drying operation when the drying result is adequate. For this just one technically simple and economical temperature sensor with associated signal evaluation is required according to the invention. Naturally two or more temperatures disposed in different positions can also be used, their temperature signals being linked to obtain the characteristic temperature, for example by forming a temperature difference.
[0012] With conventional dishwashers a value for the duration and initial temperature respectively of the drying operation that is suitable for a predetermined standard load is permanently programmed in for the duration of the drying operation and its initial temperature in a program sequence controller.
[0013] In a further embodiment of the invention the dishwasher has means for detecting the load or the load quantity. The initial temperature for a drying operation with inherent heat is determined before the start of the drying operation as a function of the detected load. A suitable initial temperature and/or a quantity of thermal energy to be supplied to heat the items to be washed can also be predetermined as a function of the load before the items to be washed are heated. The load here can be expressed for example by the quantity, thermal capacity and/or total surface of the items to be washed. The drying operation can thus be optimized as a function of the load, for example being shortened in the case of a smaller load.
[0014] The characteristic temperature can essentially be detected at different places in the dishwasher. It can be a temperature characteristic of the condensation surface for example. The characteristic temperature can also be a temperature that is characteristic of the temperature of the items to be washed.
[0015] A differential temperature can be formed for example from the temperature characteristic of the tempera-
ture of the items to be washed and the temperature character-
istic of the temperature of the condensation surface. The
temperature of a thermal reservoir can optionally also serve as
the temperature of the condensation surface. Evaluating the
differential temperature reduces or eliminates the influence of
the ambient temperature and/or the installation situation and/
or the influence of the heat and sound insulation around the
washing compartment, thereby allowing the characteristic
feature to be identified even more reliably.

[0016] To achieve the abovementioned object a dishwash-
er is also proposed that has a washing compartment for items
to be washed and a condensation surface communicating with
the washing compartment and also means for heating the
items to be washed in the washing compartment.

[0017] According to the invention the dish washer also has
means for detecting a time dependency (T(t)) of a character-
istic temperature (T) and means for detecting a feature of the
time dependency of the characteristic temperature that is
characteristic of the degree of evaporation of water from the
surface of the items to be washed. This allows the actual end
of the drying operation to be determined. It can also be deter-
mined as a function of load so that the drying operation is
terminated as required.

[0018] The loading door can serve as the condensation
surface for example. Since in the case of conventional dish-
washers the loading door already holds electronic compo-
nents and elements of the sequence controller, a temperature
sensor can be built in there economically with little additional
technical outlay. The condensation surface preferably com-
unicates in a thermally conducting manner with an element
of high thermal capacity, for example with a water or thermal
reservoir regulated to a relatively low temperature. The con-
densation surface can then be a surface of the thermal reser-
voir communicating with the washing compartment. The
temperature of the condensation surface only changes sig-
nificantly as the items to be washed are heated, bringing about
an effective condensation and therefore also drying effect.
The influence of the ambient temperature (e.g. summer, win-
ter) or the installation situation (e.g. proximity to other heat-
generating appliances) on the characteristic temperature is at
least reduced due to the high thermal capacity of the water or
thermal reservoir.

[0019] The detection means can be configured to detect the
time dependency of a temperature characteristic of the tem-
perature of the condensation surface and can for example be
a temperature sensor coupled thermally to the condensation
surface. Alternatively the detection means can be configured
to detect the time dependency of a temperature characteristic
of the temperature of the items to be washed and can for ex-
ample be a temperature sensor coupled thermally to water
circulated through the washing compartment. An appropriate
location for this can be the pump sump of the automatic
machine for example.

[0020] The detection means can comprise one or more of
the following means: (i) means for identifying that an end
value is reached, (ii) means for identifying the start of an
asymptotic behavior as the end value of the characteristic
temperature is approached, (iii) means for identifying that a
threshold of time dependency is reached and/or (iv) means for
identifying a threshold of the derivation according to time or
the temporal derivation of the time dependency of the char-
acteristic temperature. These means can be implemented in
the form of software modules, which evaluate temperature
measurement signals of the detection means. A central con-

roller can also be provided with a processor that can be
programmed using software.

[0021] The dishwasher can also have means for supplying
the first derivation according to time of the time dependency
of the characteristic temperature and the detection means can
have means for identifying that an end value is reached or the
start of an asymptotic behavior as the end value of the tem-
poral derivation of the characteristic temperature is
approached. Alternatively it can have means for identifying
that a threshold of time dependency or a threshold of the
temporal derivation of the time dependency of the character-
istic temperature has been reached. These means can also be
provided in the form of software modules executed in the
processor.

[0022] It is possible to use the temperature characteristic of
the temperature of the items to be washed and the temperature
characteristic of the temperature of the condensation surface
or the surface of the temperature reservoir to calculate a
differential temperature. To measure the temperature of the
items to be washed a first temperature sensor can be disposed
in a circulation circuit of the water circulated through the
washing compartment, for example in a circulation pump.
Alternatively the temperature measurement can be carried out
on a medium that exchanges heat with the items to be washed,
for example the basket holding the items to be washed, or in
the washing compartment, e.g. in proximity to the receiving
site for the items to be washed. To measure the temperature of
the condensation surface it is possible to use a second tem-
perature sensor in thermal contact with the condensation sur-
face or the surface of the temperature reservoir. By forming
and evaluating a temperature difference it is also possible to
reduce or eliminate the influence of the ambient conditions or
the installation situation on the control of the drying opera-
tion.

[0023] Provision is also preferably made for a tempera-
ture characteristic of the items to be washed and/or a tempera-
ture characteristic of the condensation surface to be detected
and evaluated. To this end provision can also be made for the
various measured values to be weighted differently before they
are evaluated.

[0024] In a dishwasher with a thermal reservoir for example
one embodiment of such a detection and calculation facility
can have a first temperature sensor in the reservoir. A second
sensor can be disposed in the washing compartment and a
third in the detergent dispenser in the loading door. The cal-
culation facility in each instance forms a ratio value (quotient)
from simultaneously detected values of the second and third
sensors and subtracts this from a simultaneously measured
temperature value of the first sensor. A curve with a falling
gradient, which approximates asymptotically to a tempera-
ture as a threshold, results for a number of time points
detected within a time interval. The threshold symbolizes
complete drying. If the curve has approximated to this up to a
certain approximation sum or even reaches the threshold, the
control unit receives a corresponding signal, whereupon it
terminates the drying operation.

[0025] The principle of the invention is described in more
detail below by way of example with reference to a drawing,
in which:

[0026] FIG. 1 shows the time dependency of a temperature
during the operations in the washing compartment of a dish-
washer with inherent heat drying;
FIG. 2 shows the time dependency of the temperature in the washing compartment of the dishwasher during the final rinse and drying operations for different loads;

FIG. 3 shows a schematic cross section (side view) of a dishwasher; and

FIG. 4 shows a schematic cross section (front view) of a dishwasher with a temperature reservoir.

FIG. 1 shows operations in a dishwasher with inherent heat drying according to the prior art. They comprise a prewash operation 2, a first cleaning operation 4, a second cleaning operation 6, an intermediate rinse operation 8, a final rinse operation 10 and a drying operation 12 that completes the operations. In the prewash operation 2 cold fresh water (approx. 3.4-3.9 ºC) is fed in and circulated through the washing compartment 14 (see FIGS. 3 and 4) for a preset period of approx. 15 mins by means of a circulation pump 20 disposed below the washing compartment 14. In the subsequent cleaning operation 4 detergent is introduced into the washing compartment 14 and the fresh water fed in for the prewash is heated to an initial cleaning temperature of approx. 51º C. for a period of approx. 13-14 mins. A heating apparatus (not shown) disposed in the hydraulic circuit heats the circulated water to the temperature desired in each instance in an operation. In the subsequent cleaning operation 6 the heated water, now provided with detergent, is circulated. The cleaning operation 6 represents the main cleaning operation for the dishes 28 disposed in the washing compartment 14.

Between the cleaning operation 6 and the intermediate rinse operation 8 the washing water is pumped out of the washing compartment 14 and clean fresh water is fed in. The fresh water is circulated for a period of approx. 5 mins during the intermediate rinse operation 8 and is heated in the process by contact with the elements in the washing compartment 14 that are still warm from the cleaning operation 6, for example the items to be washed 28, 28a, 28b, a basket 30, a water spray rotating arm 24 and the walls of the washing compartment 14 as well as elements in a circulation circuit 22a, 20, 22b. To switch from the intermediate rinse operation 8 to the subsequent final rinse operation 10 the intermediate rinse water is pumped out of the washing compartment 14 and cold fresh water is fed in again.

In known dishwashers with inherent heat drying the cold fresh water fed in is circulated for a predetermined fixed time, e.g. approx. 15 mins, in the final rinse operation 10 and in this process heated with a predetermined fixed heat output to the initial temperature 10 for the final drying operation 12, e.g. to approx. 65º C.

FIG. 2 shows the gradient of temperature over time T_m(t) for the smaller load n-drops more steeply or quickly at the start of the drying operation than for the standard load n and the asymptotic state is reached earlier at the temperature T_1,2,n_ at time t_{1,2,n_} than for the standard load, because overall there is a smaller quantity of moisture to be evaporated from the surface of the items to be washed 28. Conversely the temperature T_m(t) for the larger load n+ drops less steeply at the start of the drying operation than for the standard load n and the asymptotic state is reached later at the temperature T_1,2,n_ at time t_{1,2,n_}.

The complete drying of the items to be washed 28 as a function of the load is identified by detecting the reaching of the asymptotic state of the temperature gradient. This can be used to terminate the drying operation 12 when complete drying has been achieved and thus always to achieve an adequate drying result (complete drying) as a function of the load. The drying operation is therefore optimized compared with a drying operation with permanently programmed sequence parameters (fixed initial temperature, fixed drying time), as the drying operation 12 can be terminated earlier for a smaller load than it can with conventional automatic dishwashers with a permanently set drying period.
In the description above it has been assumed that the characteristic temperature is a temperature in the washing compartment 14, e.g. the temperature of the items to be washed 28a, 28b. The characteristic temperature can however also be another measured temperature variable, as in the embodiments of the invention illustrated in FIGS. 3 and 4.

A dishwasher according to FIG. 3 comprises a washing compartment 14, in which the items to be washed 28, specifically plates and cups, are placed in a basket 30, a loading door 16 hinged to the washing compartment 14, which is closed during the operations shown in FIG. 1, a water spray rotating arm 24 with a number of spray nozzles 26 which is disposed in a rotatable manner in the washing compartment 14, a circulation pump 20 disposed below a base wall 19 of the washing compartment 14, an inlet 22a of the circulation line, which connects a pressure output side of the circulation pump 20 to the water spray rotating arm 24, an outlet 22b of the circulation line, which is connected to an intake side of the circulation pump 20, and a first temperature sensor 32 and a second temperature sensor 34, each connected by way of electrical or optical lines to corresponding temperature readout apparatus for evaluating the temperature measurement signals generated by the temperature sensors 34, 36.

The first temperature sensor 32 is disposed in the circulation pump 20. It serves to measure a temperature T1 or to detect the time dependency T1(t) of the washing liquor in the circulation circuit. It can however also be disposed at different positions in the circulation circuit, for example in the inlet 22a, outlet 22b or in a depression in the base wall of the washing compartment 14 in proximity of the opening of the outlet 22b.

The second temperature sensor 34 is disposed in contact with the inner wall, i.e. the wall of the loading door 16 facing the washing compartment 14. It serves to measure a reference temperature T2 or to detect the time dependency of the reference temperature T2(t), which is characteristic of the temperature of a cold surface in the washing compartment 14. It can however also be disposed in different positions, for example in a control panel 18 in the loading temperature 16, where it can easily be connected to the associated temperature readout apparatus by means of electric cables that are present there anyway.

The characteristic temperature T(t) for detecting a characteristic feature is the difference between the temperatures T1 and T2, i.e. T(t)=ΔT_{12}(t)=T1(t)−T2(t). The temperature T1 of the water measured by the first temperature sensor 32 in the circulation circuit will drop after the heat output is deactivated at the end of the final rinse operation from the start of the drying operation. The gradient over time T1(t) can be illustrated by a curve that drops over the course of time with a form similar to the form shown in FIG. 2. The temperature T2 measured by the second temperature sensor 34 at the condensation surface rises during the final rinse operation due to heat transfer into and through the walls of the washing compartment, but more slowly than the temperature T1. After the start of the drying operation the temperature T2 continues to rise due to the condensation heat released during condensation of the water evaporated from the items to be washed at the cold surface in the washing compartment. This further rise of T2 is however smaller than the drop of T1, so the gradient over time of the temperature difference ΔT_{12}(t)=T1(t)−T2(t) generally has a falling gradient. The feature characteristic of the achievement of complete drying of the items to be washed is the falling below an approximately selected critical value characteristic of complete drying, i.e. a threshold for ΔT_{12}.

Unlike the dishwasher illustrated in FIG. 3 the dishwasher in FIG. 4 also has a thermal reservoir 38 as a temperature reservoir, which is located on a side wall of the washing compartment 14. The thermal reservoir 38 is configured in the form of a vessel disposed parallel to the side wall of the washing compartment 14. It essentially comprises two walls disposed parallel to each other, a supply line 40a with a controllable inlet valve 42 for filling the thermal reservoir 38 with water and an outlet line 40b for emptying the thermal reservoir. As with the embodiment in FIG. 3 a first temperature sensor 32 for measuring a temperature T1 or for detecting its time dependency T1(t) of the washing liquor is disposed in the circulation circuit. Instead of the second temperature sensor 34 located in the loading door (see FIG. 3) a third temperature sensor 36 is disposed in contact with the wall of the thermal reservoir 38 facing the washing compartment 14. It serves to measure a reference temperature T3 or to detect its time dependency T3(t), which is characteristic of the temperature of the water in the thermal reservoir 38.

At the start of the final rinse operation or at the start of the drying operation the thermal reservoir 38 is filled with relatively cold fresh water compared with the circulated washing liquor. The temperature T3 in the thermal reservoir 38 rises during the final rinse operation due to heat transfer into and through the walls of the washing compartment 14, but more slowly than the temperature T1. The rise in the temperature T3 from the start of the drying operation is produced by heat released by condensation of the water evaporated from the items to be washed 28a, 28b on the cold side wall of the washing compartment 14, adjacent to which the thermal reservoir 38 is located. The characteristic temperature T(t) for detecting the characteristic feature is the temperature T3 in the thermal reservoir, i.e. T(t)=T3(t). The characteristic feature for achieving complete drying of the items to be washed here is the exceeding of an appropriately selected critical value characteristic of complete drying, i.e. a threshold for T3.

A suitable control circuit makes it impossible to open the loading door 16 during the final rinse and drying operations 10 and 12. This makes it possible to prevent the items to be washed being wet due to back condensation when the loading door is opened.

LIST OF REFERENCE CHARACTERS

- Prewash operation/prewashing
- Cleaning operation/cleaning
- Intermediate rinse operation/intermediate rinsing
- Final rinse operation/final rinsing
- Drying operation/drying
- Washing compartment
- Loading door
- Control panel
- Base plate
- Circulation pump
- Inlet of circulation line
- Outlet of circulation line
- Water spray rotating arm
- Spray nozzles
- Items to be washed
- Basket
12. A method for regulating a drying period in a dishwasher having a washing compartment for receiving items to be washed, the items to be washed being heated to a predetermined initial temperature, which is above a temperature of a condensation surface communicating with the washing compartment, the method comprising the steps of:

detecting a temperature gradient of a characteristic temperature during drying of the items to be washed,

using the temperature gradient of the characteristic temperature to detect a feature that is characteristic of a degree of evaporation of water from a surface of the items to be washed.

13. The method as claimed in claim 12, wherein reaching of an end temperature or a start of an asymptotic behavior of a time dependency of the characteristic temperature is detected as the feature.

14. The method as claimed in claim 12, wherein rises in the temperature gradient of the characteristic temperature are evaluated to detect the feature.

15. The method as claimed in claim 12, wherein the characteristic temperature is a temperature characteristic of at least one of a temperature of the items to be washed and a characteristic temperature of the condensation surface.

16. The method as claimed in claim 12, further comprising at least one of measuring a temperature characteristic of a temperature of the items to be washed and detecting a temperature gradient of the temperature characteristic of the temperature of the items to be washed.

17. The method as claimed in claim 16, wherein the characteristic temperature is a differential temperature between the temperature characteristic of the temperature of the items to be washed and a temperature characteristic of the temperature of the condensation surface.

18. The method as claimed in claim 17, wherein the dishwasher includes a water reservoir and the temperature characteristic of the temperature of the condensation surface is a temperature characteristic of the temperature of the water reservoir.

19. The method as claimed in claim 18, wherein at least one of a temperature characteristic of the items to be washed and a temperature characteristic of the condensation surface are detected and evaluated.

20. A dishwasher, comprising:
a washing compartment for items to be washed;
a condensation surface communicating with the washing compartment;
a heater for heating the items to be washed in the washing compartment to a predetermined initial temperature, which is above a temperature of the condensation surface;
means for detecting a time dependency of a characteristic temperature; and
means for detecting a feature of the temperature gradient of the characteristic temperature that is characteristic of a degree of evaporation of water from a surface of the items to be washed.

21. The dishwasher as claimed in claim 20, wherein the detection means comprise at least one of:

means for identifying that an end value is reached;
means for identifying a start of an asymptotic behavior as an end value of the characteristic temperature is approached;
means for identifying that a threshold of time dependency is reached; and
means for identifying a threshold of a derivation of the time dependency of the characteristic temperature according to time.

22. The dishwasher as claimed in claim 20, wherein the means for detecting a time dependency comprise:

a first temperature sensor structured to detect the time dependency of the temperature characteristic of the temperature of the items to be washed; and
a second temperature sensor structured to detect the time dependency of the temperature characteristic of the condensation surface.