Method for controlling the operation of an oven

The present invention relates to a method for controlling the operation of an oven (3). A fan (21) is turned on to circulate air within an interspace (19) between the muffle (12) of the oven (3) and an outer body (8) of the oven. The fan (21) is controlled depending on the selected cooking program and on a temperature measured in the proximity of a control unit (20) of the oven (3), placed within the interspace (19).
The present invention relates to a method for controlling the operation of an oven according to the preamble of claim 1, as well as to an oven implementing such a method.

It is known that ovens, in particular built-in ones, include a cooling fan which sucks air from the external environment and circulates it within an interspace between the muffle and the outermost structure of the oven.

In general, air enters the oven through the door thereof, which is thus cooled, and after having flowed through said interspace it goes out of the oven again.

Within the interspace the electronic control unit of the oven is typically placed, which is thus cooled by the air sucked by the fan.

In order to prevent the electronic control unit from overheating, the cooling fan is normally kept turned on for the entire cooking cycle.

However, operation of the cooling fan and air circulation within the interspace of the oven produce noise.

For this reason, patent JP2004047305 proposes to vary the fan revolution speed as a function of the heating element in use.

Patent US2005077288 discloses the idea of adjusting the operation of a fume extractor fan (in particular its speed or the instant at which it is turned on) depending on the selected cooking program or on the humidity inside the muffle. Although effective, these patents do not deal with improving the energetic efficiency of the oven.

On the contrary, the Applicant has found in the cooling fan control an element which may improve the energetic efficiency of the oven.

The air circulation within the interspace of the oven, in fact, has the effect of extracting the air from the muffle and partially cooling the walls thereof, so that, as a result, the oven requires more energy to complete the cooking process.

It is the object of the present invention to provide a method for controlling the oven, in particular the cooling fan thereof, which allows to reduce its energy consumption and to improve its energetic efficiency.

These and other objects are achieved through a method for controlling the operation of an oven incorporating the features set out in the appended claims, which are intended as an integral part of the present description.

The present invention is based on the idea of controlling the operation of the cooling fan depending on the selected cooking program and on the temperature of the electronic control unit.

This improves the energetic efficiency of the oven, since only the heat necessary for preventing the electronic components from overheating or an excess moisture in the muffle which may impair the cooking process are removed from the oven. Advantageously, the temperature of the control unit is sampled at regular intervals, and the fan is turned on when the temperature of the control unit exceeds a reference value.

In particular, the cooling fan is turned on at a speed which depends on the difference between the measured temperature and said reference value.

In this manner, during the final steps of the cooking cycle, i.e. when the temperature is high and the differences between the measured temperature and the reference temperature are greatest, the fan is turned on frequently at a high speed to extract a large part of the humidity present in the muffle, whereas during the initial step of the cooking cycle, i.e. when the muffle is warming up, the fan stays off to avoid extracting too much heat.

Advantageously, the speed at which the fan is operated is in any case lower than or equal to a maximum value which depends on the selected cooking program or on which heating elements are being used in the cooking process.

In this manner, more or less humidity will be extracted from the muffle according to the type of cooking going on, thus obtaining better cooking results.

In addition or as an alternative to controlling the fan speed, the fan operating time may also be adjusted as a function of the difference between the measured temperature and the reference temperature.

This allows the fan to be controlled in the most appropriate way to find the best possible compromise between energy consumption, protection of the electronic components and cooking results.

In a possible embodiment, the fan is always operated at the same preset speed, while the fan operating time depends on the difference between the measured temperature and the reference temperature.

Compared to the one including fan speed adjustment, this solution is characterised by a slower response to the increase in the temperature of the electronic components, which are hence more subject to the risk of failure, but it provides a more gradual reduction of the humidity in the muffle, so that it may be more suitable for some kinds of cooking programs, such as steam cooking programs.

Further objects and advantages of the present invention will become apparent from the following description and from the annexed drawings, wherein:

- Fig. 1 shows a kitchen cabinet comprising an oven;
Fig. 2 shows a front view of the oven of Fig. 1; 
Fig. 3 shows a sectional view of the oven of Fig. 1; 
Fig. 4 shows the trend over time of the temperature measured in the proximity of the control unit of the oven of Fig. 1, and the corresponding trend of the revolution speed of a cooling fan; 
Fig. 5 shows the curves of Fig. 4 when the fan is controlled in accordance with a second embodiment of the present invention.

[0025] Fig. 1 shows a kitchen cabinet 1 with a built-in refrigerator 2 and an oven 3 being flush-mounted inside a recess 4 of the cabinet.

[0026] The oven 3 is fitted with a control panel 5 comprising knobs 6 and a display 7, through which the user can select the cooking parameters, in particular temperature and time, and possibly preset cooking programs as well.

[0027] Fig. 1 also shows the shell 8 acting as an outer body of the oven and enclosing the rear portion thereof, while in front there is a door 9 provided with a handle 10 and an inspection glass 11.

[0028] Fig. 2 shows a front view of the oven 3 with the door 9 open.

[0029] In this figure it is possible to see the muffle 12 defining a cooking compartment 13 in which the food to be cooked can be placed; reference numeral 28 shows a baking pan positioned inside the cooking compartment.

[0030] Fig. 3 shows a vertical section of the oven 3.

[0031] The oven is an electric one and includes, inside the muffle 12, a pair of heating elements which, in this example, consist of a grill resistor 14 located in the proximity of the muffle ceiling and a circular resistor 15 located on the side opposite to the door 9.

[0032] Inside the muffle 12 there is also a fan 16 driven by a motor 17; the fan is mounted with its axis of rotation concentric to the circular resistor 15, so that when the resistor is heated the rotating fan will generate a hot air flow inside the oven. For safety reasons, the fan is located behind a guard 18 consisting of a perforated panel mounted on the vertical side of the muffle.

[0033] Between the muffle 12 and the shell 8 there is an interspace 19 within which the electronic control unit 20 and the cooling fan 21 are arranged.

[0034] Rotation of the fan 21 external to the muffle generates a flow F of air which is drawn from the outside environment through a number of apertures 22 obtained in the base of the shell 8 and then flows out of the oven through the interspace 12.

[0035] Within the interspace 19 there is the electronic control unit 20, which is connected to the control panel 5 through cables 23 for receiving the user’s commands and displaying useful information on the display 7, e.g. information about the selected cooking program. Through electric connections 24, the control unit 20 controls the activation of the fans 16 and 21 and of the resistors 14 and 15, so as to appropriately adjust the temperature inside the oven.

[0036] The control unit 20 is positioned in a manner such as to be hit by the air flow generated by the fan 21.

[0037] Since said flow comes from the outside, its temperature is lower than that of the air within the interspace, thus cooling the electronic control unit 20.

[0038] In this embodiment example, the interspace 19 is in fluidic communication with the muffle 12 through the chimney 25.

[0039] The air circulation caused by the fan 21 within the interspace 19 has therefore the effect of extracting the fumes from the muffle 12.

[0040] Within the interspace 19 there is also a temperature sensor 26 which detects a temperature in the proximity of the control unit 20.

[0041] Preferably, this temperature sensor is mounted on the same printed circuit board (PCB) that accommodates other components, such as a microcontroller, of the control unit 20.

[0042] The temperature sensor 26 is operationally connected to the control unit 20, so that the latter can receive the information about the temperature detected by the sensor 26.

[0043] Aiming at energy consumption optimisation, the control unit 20 controls the operation of the fan 21 as a function of the temperature measured by the sensor 26. Because the electronic control unit can still operate properly up to temperatures of 45-50°C, the fan will only be turned on when the sensor detects a temperature which might damage the control unit, or anyway which might cause it to malfunction.

[0044] Thus, instead of being kept constantly on through the whole cooking program, the fan is turned on or off depending on the temperature measured in the proximity of the electronic control unit, i.e. depending of what may be defined as control unit temperature.

[0045] Since the fan 21 also acts as an extractor of the fumes from the muffle 12, said fan 21 is also controlled in a manner such as to keep inside the muffle 12 a correct humidity level for the cooking program selected by the user or for a specific cooking step of the selected program.

[0046] For example, depending on whether a grill step or a steam cooking step is going on, a different degree of humidity will have to be kept inside the muffle 12 in order to attain good cooking results.
The control unit 20 will thus control the fan 21 in such a way as to keep the degree of humidity within a proper range to ensure good cooking results, without at the same time dissipating too much energy.

Furthermore, depending on whether the heating elements are on or off, the temperature gradient in the proximity of the control unit will vary, so that, in order to save energy, the fan may be operated at a different speed according to how many and/or which elements are on.

In particular, all other conditions being equal, the fan will be operated at a lower speed if the elements are off.

This type of control can be accomplished by using a humidity sensor 27 located in the muffle and operationally connected to the control unit 20.

More preferably, in order to reduce the number of components and simplify the oven control, the fan is controlled as a function of the ongoing program or cooking step, or else as a function of the active heating elements (in this example, the resistors 14 and 15).

In a first preferred embodiment, the fan 21 is controlled depending on the difference between the temperature measured by the sensor 26 and a reference value.

More preferably, in order to reduce the number of components and simplify the oven control, the fan is controlled as a function of the ongoing program or cooking step, or else as a function of the active heating elements (in this example, the resistors 14 and 15).

In a first preferred embodiment, the fan 21 is controlled depending on the difference between the temperature measured by the sensor 26 and a reference value.

To this end, the control unit 20 is provided with a suitable control algorithm which adjusts the fan revolution speed to a value that depends on said temperature difference.

For this purpose, the control unit 20 samples the temperature at regular intervals, and at each reading it determines whether the fan must be turned on or not and, if yes, at what speed.

In order to take into account both energetic balance and cooking requirements, the fan 21 is operated at a speed which depends on both the temperature measured in the proximity of the electronic unit and the cooking type.

The maximum revolution speed of the fan is set according to the type of cooking being carried out or to the active heating elements.

In a first embodiment, the actual speed of the fan is calculated according to the following relation:

\[ v_{\text{eff}} = \begin{cases} v_{\text{max}} & \text{per } \Delta T \geq \Delta T_{\text{max}} \\ \alpha \cdot \Delta T \cdot v_{\text{max}} & \text{per } 0 < \Delta T < \Delta T_{\text{max}} \\ 0 & \text{per } \Delta T \leq 0 \end{cases} \]

where \( v_{\text{max}} \) is the maximum speed set for the ongoing cooking cycle or cooking step, \( \Delta T = T - T_{\text{ref}} \) is the difference between the temperature measured by the sensor 26 and the reference temperature, \( \Delta T_{\text{max}} \) is a preset value, \( \alpha \) is a constant obtained empirically and preferably dependent on the type of cooking program being carried out.

Fig. 4 shows the trend of the curves of the temperature measured in the proximity of the control unit and of the fan speed as a function of time, when the speed is calculated according to (1).

Initially, the fan 21 is off, so that the temperature measured in the proximity of the electronic control unit rises quickly due to the muffle 12 warming up and to the hot air flowing out of the chimney 25.

At time \( t_1 \), the temperature is measured by the sensor 26, and it is detected that it is lower than the reference temperature \( T_{\text{ref}} \), beyond which the fan must be turned on.

At time \( t_2 \), the temperature is equal to \( T_{\text{ref}} \), and therefore the fan stays off.

At time \( t_3 \), the temperature exceeds \( T_{\text{ref}} \) and the temperature difference is greater than \( \Delta T_{\text{max}} \); hence the fan is turned on at the maximum speed \( v_{\text{max}} \) set for the type of cooking being carried out at time instant \( t_3 \).

At time \( t_4 \), the temperature measured in the proximity of the control unit still exceeds \( T_{\text{ref}} \), but \( \Delta T \) is smaller than \( \Delta T_{\text{max}} \); consequently, the fan is turned on at a speed \( v_1 \), lower than \( v_{\text{max}} \) and calculated, for example, according to the equation (1).

At time \( t_5 \), the measured temperature is lower than \( T_{\text{ref}} \), and therefore the fan is turned off.

At time \( t_6 \), the temperature exceeds \( T_{\text{ref}} \) and the difference with respect to the reference temperature is equal to what was measured at time \( t_4 \), so that the fan is turned on at the same speed \( v_1 \).

As an alternative to the equation (1), the fan revolution speed may be chosen by using other mathematical laws which relate the fan speed to the measured temperature and to the ongoing cooking program.

In particular, in a preferred and advantageous embodiment, the law that regulates the fan revolution speed depends on at least two temperature values measured in the chamber; in particular, it depends both on the measured instantaneous temperature and on historical temperature values, i.e. values previously measured by the control unit.

This optimises the response of the control system, and the fan revolution speed is changed less abruptly than in Fig. 4.

Such a type of control, which also takes into account historical temperature readings, may be attained through a PID (Proportional-Integral-Derivative) controller and a memory area (possibly internal to the PID controller) which stores the temperature values measured in the cooking chamber by the sensor 26.
The values stored in this memory area represent the history of the cooking chamber temperatures and are used by the PID controller along with the measured instantaneous temperature in order to determine the actual speed at which the fan must be operated.

In this case, therefore, the fan is operated at an actual speed which is calculated according to the following law:

\[
\begin{cases}
    v_{\text{eff}} = \frac{v_{\text{max}}}{\Gamma} \cdot v_{\text{max}} & \text{per } \Gamma \geq 1 \\
    0 & \text{per } 0 < \Gamma < 1 \\
    \frac{d\Delta T(t)}{dt} & \text{per } \Gamma \leq 0
\end{cases}
\]

\[
\Gamma = \left( \alpha_1 \cdot \Delta T + \alpha_2 \cdot \int_{t_{\text{start}}}^{t_{\text{end}}} \Delta T(t) dt + \alpha_3 \cdot \frac{d\Delta T(t)}{dt} \right)
\]

where \(v_{\text{max}}\) is the maximum speed set for the ongoing cooking cycle or cooking step, \(\Delta T = T - T_{\text{ref}}\) is the difference between the temperature measured by the sensor and the reference temperature, \(\alpha_1, \alpha_2\) and \(\alpha_3\) are constants obtained empirically and preferably dependent on the type of cooking program being carried out, \(t_{\text{start}}\) and \(t_{\text{end}}\) are two time instants which delimit the time interval that defines the “history” to be taken into account, e.g. a time interval which ends at the instant when the actual speed is calculated and whose length equals the time elapsed between three or four updates of the fan revolution speed.

For example, referring to Fig. 4, if \(t_{\text{end}}\) is equal to \(t_5\), then \(t_{\text{start}}\) may be \(t_1\) or \(t_2\) or the oven start-up time.

Irrespective of how the actual operating speed of the fan is calculated, in the example of Fig. 4 the fan stays on, after having been turned on, until the next control unit temperature reading takes place.

Alternatively, the fan may be turned on for a predetermined time period shorter than the time elapsing between a temperature reading and the next.

In this case, the greater the difference between the measured temperature and the reference temperature, the longer the fan on time within the time interval between a temperature reading and the next.

The fan on time may also depend on the cooking type and/or on the state of the muffle heating elements.

In this case, the fan may be turned on for a time which depends on the detected temperature difference and on the selected cooking program.

For example, the fan on time may be defined in accordance with the following relation:

\[
\begin{cases}
    t_{\text{eff}} = \frac{t_{\text{max}}}{B \cdot \Delta T \cdot t_{\text{max}}} & \text{per } \Delta T \geq \Delta T_{\text{max}} \\
    0 & \text{per } \Delta T < \Delta T_{\text{max}} \\
    \frac{t_{\text{max}}}{B} & \text{per } \Delta T \leq 0
\end{cases}
\]

where \(t_{\text{max}}\) is the maximum time set for the ongoing cooking cycle or cooking step, \(\Delta T = T - T_{\text{ref}}\) is the difference between the temperature measured by the sensor and the reference temperature, \(B\) is a constant obtained empirically and preferably dependent on the type of cooking program being carried out.

In the example of Fig. 5, \(t_{\text{max}}\) is equal to the time interval between two successive readings; however, \(t_{\text{max}}\) may also be longer than said interval; in such a case, the speed will be updated every \(t_{\text{max}}\).

In this example, when at the instant \(t_3\) a control unit temperature higher than \(T_{\text{ref}}\) is detected such that the temperature difference is greater than \(\Delta T_{\text{max}}\), the fan is turned on at the maximum speed (set beforehand for the type of cooking being carried out at time \(t_3\)) for the whole time interval \(t_3-t_4\).

At time \(t_4\), the temperature measured in the proximity of the control unit is still higher than \(T_{\text{ref}}\), but \(\Delta T\) is smaller than \(\Delta T_{\text{max}}\); consequently, the fan is turned on for a shorter time.

As an alternative to the equation (3), the on time of the fan may be calculated by means of an equation which also takes into account the historical temperature trend in the cooking chamber.

Said temperature trend is stored in a memory area accessible to the control unit, as previously stated with
reference to the use of a PID controller for calculating the fan operating speed.

For example, the on time may be determined based on the following equation:

\[
 t_{\text{eff}} = \begin{cases} 
 t_{\text{max}} & \text{per } \Gamma \geq 1 \\
 \Gamma \cdot t_{\text{max}} & \text{per } 0 < \Gamma < 1 \\
 0 & \text{per } \Gamma \leq 0 
\end{cases}
\]

\[
 \Gamma = \left( \beta_1 \cdot \Delta T + \frac{\beta_2}{\beta_3} \cdot \int_{t_{\text{start}}}^{t_{\text{end}}} \Delta T(t) dt + \frac{\beta_3}{\beta_2} \cdot \frac{d\Delta T(t)}{dt} \right)
\]

where \( t_{\text{max}} \) is the maximum time set for the ongoing cooking cycle or cooking step, \( \Delta T \) is the difference between the temperature measured by the sensor 26 and the reference temperature, \( \beta_1, \beta_2 \) and \( \beta_3 \) are constants obtained empirically and preferably dependent on the type of cooking program being carried out, \( t_{\text{start}} \) and \( t_{\text{end}} \) are two time instants which delimit the time interval that defines the “history” to be taken into account, as described above with reference to the equation (2).

Of course, a man skilled in the art wanting to control the operation of the air cooling and extractor fan in accordance with the above-described teachings may make many changes to the above-described examples and adjust many other parameters (such as the fan on time) without departing from the protection scope of the present invention as set out in the appended claims.

For example, the maximum fan operating speed may be determined as a function of the humidity measured inside the muffle or of the temperature inside the muffle. In these two cases, the maximum speed will vary dynamically during the cooking cycle.

Likewise, the invention is also applicable to ovens having a different arrangement of the various elements other than the one described with reference to Figs. 1 to 3. For example, the oven control unit may be located upstream of the fan 21, provided that it is still hit and cooled by an air flow generated by the fan.

Claims

1. A method for controlling the operation of an oven (3), wherein a fan (21) is turned on in order to circulate air within an interspace (19) between the muffle (12) of the oven (3) and an outer body (8) of the oven, the method providing for controlling the fan (21) depending on the selected cooking program, characterised in that said fan (21) is also controlled depending on a temperature measured in the proximity of a control unit (20) of the oven (3) placed within said interspace (19).

2. A method according to claim 1, wherein said fan is controlled depending on at least two temperature values measured in the proximity of said control unit (20), said two temperature values being measured at different time instants.

3. A method according to claim 1 or 2, wherein the fan (21) is operated at a different speed according to how many and/or which muffle heating elements are switched on.

4. A method according to claim 1 or 2 or 3, wherein said fan is operated at a speed that depends on the difference \( \Delta T \) between said measured temperature and a reference temperature \( T_{\text{ref}} \).

5. A method according to claim 4, wherein, when said temperature difference \( \Delta T \) exceeds a reference value \( \Delta T_{\text{max}} \), said fan is operated at a maximum speed \( v_{\text{max}} \) which depends on the selected cooking program or on the active muffle heating elements.

6. A method according to claim 5, wherein, when said temperature difference \( \Delta T \) is smaller than a reference value \( \Delta T_{\text{max}} \), said fan is operated at an actual speed \( v_\lambda \) that depends on said maximum speed \( v_{\text{max}} \) and on the difference \( \Delta T \) between said measured temperature and a reference temperature \( T_{\text{ref}} \).

7. A method according to any one of the preceding claims, wherein said fan (21) is turned on for a time which depends on said temperature difference \( \Delta T \).
8. A method according to claim 7, wherein said time depends on the ongoing cooking program or on the active muffle heating elements.

9. A method according to claim 7 or 8 when dependent on claim 1, wherein said fan (21), when turned on, is operated at a revolution speed \( (v_{\text{max}}) \) which depends on the ongoing cooking program or on the active heating elements.

10. A method according to any one of the preceding claims, wherein said revolution speed depends on the humidity or temperature inside said muffle.

11. An oven comprising
   a shell (8), in which a food cooking muffle (12) is arranged,
   a fan (21) adapted to circulate air within an interspace (19) between the oven muffle (12) and the oven shell (8),
   an electronic control unit (20) arranged within said interspace and adapted to control the operation of said fan and of heating elements placed inside said muffle, and a temperature sensor (26) operationally connected to said control unit (20) and adapted to measure a temperature in the proximity of said control unit (20), characterised in that said control unit (20) is adapted to implement the method according to any one of claims 1 to 10.

12. An oven according to claim 11, wherein said control unit comprises a memory unit adapted to store at least one historical temperature value measured by said sensor (26) and a PID controller adapted to determine the fan speed depending on the instantaneous temperature reading and on said at least one historical value.
Fig. 4

Fig. 5
### DOCUMENTS CONSIDERED TO BE RELEVANT

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**TECHNICAL FIELDS SEARCHED (IPC)**
- F24C

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The present search report has been drawn up for all claims

**Place of search**: The Hague
**Date of completion of the search**: 4 November 2010
**Examiner**: Makúch, Milan

**CATEGORY OF CITED DOCUMENTS**
- T: theory or principle underlying the invention
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**P: intermediate document**

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**EUROPEAN SEARCH REPORT**

**Application Number**

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**Place of search**: The Hague

**Date of completion of the search**: 4 November 2010

**Examiner**: Makúch, Milan

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ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EPO file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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REFERENCES CITED IN THE DESCRIPTION

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