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(54) **A method for controlling the defrost of an evaporator in a refrigeration appliance and refrigeration appliance using such method**

(57) A method for controlling the defrost of an evaporator in a refrigeration appliance provided with a temperature sensor used for detecting temperature inside a cell of the appliance comprises measuring the evaporator temperature, applying an algorithm which, on the basis of the temperature inside the cell and the temperature of the evaporator, simulates the thermodynamic behavior of the cell, and detecting a change in any of the parameters of the above algorithm which is indicative of a need to defrost.

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Description

[0001] The present invention relates to a method for controlling defrost of an evaporator in a refrigeration appliance comprising a temperature sensor used for measuring the temperature inside a cell of the appliance.

[0002] A method of the above kind is disclosed by EP 1619456 where, starting from said measured temperature, a model is used in order to estimate the evaporator temperature. The evaporation temperature by itself doesn't provide a way to establish if a defrost is required.

[0003] EP1450230 discloses a method for controlling the temperature inside a cavity in which a computation is based on empirical values determined from the thermal behavior of the cavity. According to this method a first and a second temperature are detected, the second temperature being detected on or in the proximity of the evaporator. This method doesn't provide a way to establish if a defrost is required.

[0004] It is an object of the present invention to provide a method to evaluate in a reliable and accurate way the need to perform a defrost in a refrigerator appliance, estimating the amount of frost accumulated over the heat exchanger.

[0005] Such object is reached thanks to the features listed in the appended claims.

[0006] According to the invention, thermal heat exchange coefficients of a model can be related to the ice collected over the evaporators. In other words, in the following preferred model the parameters k_1,k_2,k_3.are generally constant:

$$k_1 \frac{dT_{Cavity}}{dt} + T_{Cavity} = k_2 \cdot T_{HeatExchanger} + k_3$$

[0007] In the above model or algorithm T_{Cavity} is the temperature detected by the temperature sensor in the cell, while $T_{HeatExchan\ ger}$ is the temperature detected on or in the proximity of the evaporator.

[0008] Another recursive algorithm is used to detect k_1,k_2,k_3 as, for example, Least Square, Kalman, etc. We introduce $\hat{k}_1(t),\hat{k}_2(t),\hat{k}_3(t)$ to identify the estimations of the k_1,k_2,k_3. The estimations are time-dependent, updated each time new measured values T_{Cavity} , $T_{HeatExchan\ ger}$ are available.

[0009] The general criteria are:

- *The estimated parameters are constant if no ice formation occurs.*
- *The estimated parameters changes if the ice formation occurs.*

[0010] *For example:*

- $\frac{d\hat{k}_i(t)}{dt} \approx 0$ i =1,2,3 $\Rightarrow$ *No Ice* $\rightarrow$ *No DeFrost* dt
- $\frac{d\hat{k}_i(t)}{dt} \neq 0$ i = 1,2,3 $\Rightarrow$ *Ice* $\rightarrow$ *DeFrost* dt

[0011] While these parameters are constant over time, no defrost is required. If ice is present on the evaporator, then the heat exchange coefficient decreases: so time by time the frost collects over the evaporator, the estimated $\hat{k}_1(t),\hat{k}_2(t),\hat{k}_3(t)$ values change (in particular, $\hat{k}_2(t)$ decreases significantly). Once frost begins accumulating over the heat exchanger, its performance starts decreasing and the values of the three over mentioned parameters experience a significant change. Since frost formation cause the variation of the parameters, comparing their values to a pre-determined reference (i.e. their initial values after the previous defrost or at appliance start-up, when the heat exchanger is supposed to be completely ice-free) does provide the information of performance degradation.

[0012] Once the difference between the parameters and their reference value is higher than a threshold value, the request of a defrosting action is sent to the temperature control system.

[0013] Further advantages and features of the method according to the invention will become clear from the following detailed description, with reference to the attached drawing which shows schematically how the estimation algorithm is applied according to the present invention.

[0014] The first step of the method according to the invention is to build a thermo dynamical/electrical model of the system. Then the model equations are used and combined in order to obtain an equation with one or more unknown

values, whereas the other terms are assumed to be known or already estimated. An estimation algorithm is then used to estimate the unknown values. Every kind of estimation algorithm can be used, depending upon robustness requirements, linearity, stationary behavior, computational power required and so on. The applicant has used in his tests an estimation algorithm based on Least Square, but any estimation algorithm is fine (e.g. Kalman algorithms)

[0015] The method according to the invention may be applied to any refrigerating appliances, irrespective of the type of cooling circuit which is dedicated to remove heat from the cavity (i.e.: vapor compressor circuit with any type of compressor, magnetic refrigerator, Stirling cycles, thermoelectric cooling devices, etc.). Only condition required is that at least two temperature probes shall be present, one located on (or close to) the evaporator and one located within the refrigerated compartment. If power measurements are available, as well as control request representing the amount of heat instantaneously removed from the refrigerated compartment (directly, as a cooling capacity request, or indirectly, as a speed request to the compressor), their measure can be added to the model, refining the estimation precision.

Claims

1. Method for controlling the defrost of an evaporator in a refrigeration appliance comprising a temperature sensor used for detecting temperature inside a cell of the appliance, **characterized in that** it comprises measuring the evaporator temperature, applying an algorithm which, on the basis of the temperature inside the cell and the temperature of the evaporator, simulates the thermodynamic behavior of the cell, and detecting a change in any of the parameters of the above algorithm which is indicative of a need to defrost.

2. Method according to claim 1, wherein the algorithm is as follows:

$$k_1 \frac{dT_{Cavity}}{dt} + T_{Cavity} = k_2 \cdot T_{HeatExchanger} + k_3$$

where T_{Cavity} is the temperature detected by the temperature sensor in the cell, $T_{HeatExchanger}$ is the temperature detected on or in the proximity of the evaporator and k_1,k_2,k_3 are the parameters of the algorithm.

3. Method according to claim 1 or 2, wherein said parameters are estimated with any auxiliary known estimation algorithms, preferably Least Square or Kalman filters algorithms.

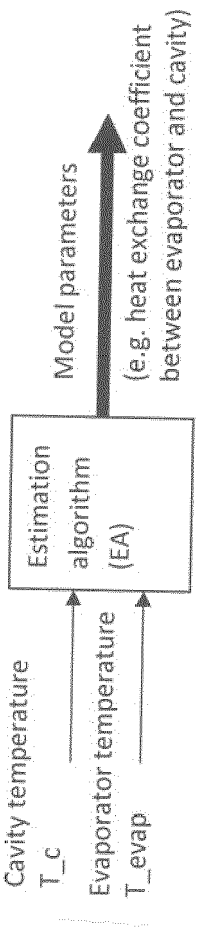
4. Refrigeration appliance having at least a cell with an evaporator, a first temperature sensor for detecting the temperature inside the cell , a second temperature sensor for detecting the temperature of the evaporator, and a control circuit for driving actuators of the refrigeration appliance, **characterized in that** the control circuit is adapted to evaluate the timing for defrosting the evaporator on the basis of an algorithm which simulates the thermodynamic behavior of the cell, any detected change in any of the parameters (k_1,k_2,k_3) of the above algorithm being indicative of a need to defrost.

5. Refrigeration appliance according to claim 4, wherein the algorithm is as follows:

$$k_1 \frac{dT_{Cavity}}{dt} + T_{Cavity} = k_2 \cdot T_{HeatExchanger} + k_3$$

where T_{Cavity} is the temperature detected by the temperature sensor in the cell, $T_{HeatExchanger}$ is the temperature detected on or in the proximity of the evaporator and k_1,k_2,k_3 are the parameters of the algorithm.

6. Refrigeration appliance according to claim 4 or 5, wherein said parameters are estimated with any auxiliary estimation algorithms, preferably Least Square or Kalman filters algorithm.


Cavity temperature
T_c
Evaporator temperature
T_evap
Estimation algorithm (EA)
Model parameters
(e.g. heat exchange coefficient between evaporator and cavity)

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EUROPEAN SEARCH REPORT

Application Number
EP 13 15 1257

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2002/088238 A1 (HOLMES JOHN S [US] ET AL) 11 July 2002 (2002-07-11) * paragraphs [0001], [0084] *	1,3,4,6	INV. F25B47/00 F25D21/06
A	US 6 131 400 A (SEOK JIN-OH [KR] ET AL) 17 October 2000 (2000-10-17) * column 4, line 66 - column 5, line 9; figures 1-3 *	1-6	
A	BORGES B N ET AL: "Transient simulation of household refrigerators: A semi-empirical quasi-steady approach", APPLIED ENERGY, ELSEVIER SCIENCE PUBLISHERS, GB, vol. 88, no. 3, 1 March 2011 (2011-03-01), pages 748-754, XP027473129, ISSN: 0306-2619, DOI: 10.1016/J.APENERGY.2010.09.019 [retrieved on 2010-10-20] * abstract * * Concluding Remarks; paragraph [005.] * * Mathematical Model; paragraph [002.] *	1-6	TECHNICAL FIELDS SEARCHED (IPC) F25B F25D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	23 May 2013	Melo Sousa, Filipe

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 15 1257

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 EDP file on
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23-05-2013

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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- EP 1619456 A **[0002]**
- EP 1450230 A **[0003]**