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(54) Improvement in the arrangement used in a clothes drying apparatus to determine the drying time

(57) Method for automatically controlling the drying cycle in a clothes drying machine until the desired dryness level is reached, said method being adapted to calculate and determine the required drying time by processing a plurality of initial temperatures (t1, t2 ...tn) of the air used to dry said clothes, as well as the corresponding times, starting from the beginning of the drying cycle, wherein said expected drying time is also calculated on the basis of a plurality of historical data out of previously run experiments, in which the different conditions of both the machine and the drying load are taken into account along with the corresponding drying result obtained.

In a preferred manner, the temperature of said air in the drum is measured when the air is exhausted out of the drum into the atmosphere.

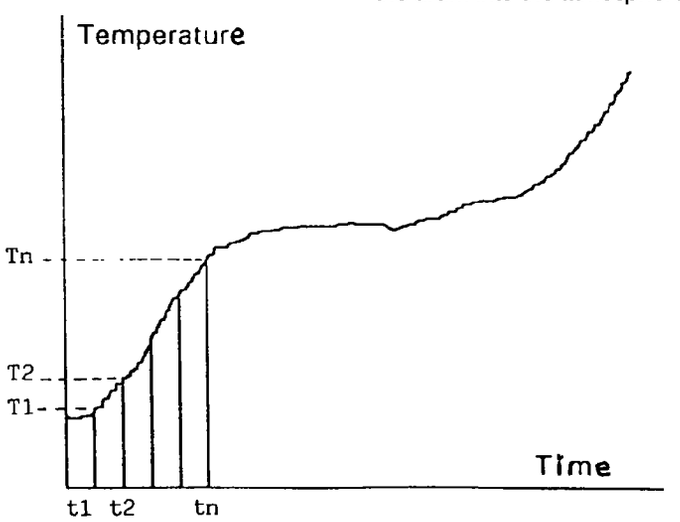

Fig. 3

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Description

The present invention refers to a drying process, in particular a clothes drying process, which does not terminate its drying cycle on the basis of a time to be pre-set by the user, or the machine itself, through a timer, but rather on the basis of the actual contents of residual moisture in the clothes making up the drying load. A peculiar feature of such a method lies in the operational contrivances enabling the time needed to reach a pre-determined degree of dryness of the clothes to be determined not only quite early in the process, but also in a fully automatic manner.

Clothes drying machines are known in the state of the art which are equipped with devices to automatically calculate the time needed to reach a pre-determined dryness level or degree. So, for instance, the German patent specification DE 3030864 to Bosch-Siemens Hausgeräte discloses an automatic clothes drying process in which the duration of the drying cycle is determined on the basis of the type of the clothes making up the drying load, as well as by processing out the temperature gradient as calculated between two subsequent moments during the initial temperature rise stage.

Such a method, however, has a main drawback in that the user is each time requested to perfectly know what kind and type of fabrics he or she is loading into the drum of the machine for drying, and then to pass on this information to the machine itself. Furthermore, since the calculation is based on a single measurement, ie. on an initial gradient of temperature, the method turns out to be quite inaccurate owing to the effect that is brought in by other factors having an influence on the drying time.

Similarly, the Japanese patent specification J 87052598 to Hitachi discloses a clothes drying method which is solely based on the measurement and the processing of the rise gradient of the temperature of the drying air and, as a consequence, suffers from the same basic drawback as the afore cited method.

The Japanese patent specification J 62148698 to Matsushita discloses a clothes drying machine in which the drying cycle is programmed on the basis of a plurality of experiments run on the machine, the gradient of temperature during an actual drying phase of the process, and some other information such as the humidity contents, the type of contact and the like, as detected by appropriate sensors.

Such a machine is actually capable of ensuring a greater accuracy in automatically calculating the expected time needed to reach a pre-determined drying level of the clothes, but it nevertheless has a main drawback in that it requires the use of additional sensors, with the accompanying functional and construction complications.

The patent specification GB 2 034 451 teaches a method according to which the drying cycle of a clothes drying machine can be terminated on the basis of the measurement and the assessment of the rise gradient of the temperature of the exhaust air. However, such a solution is actually rather inaccurate, since the temperature rise pattern depends also on a number of other important factors whose effect is not yet known.

It therefore would be desirable, and it is actually a main purpose of the present invention, to provide a method for drying clothes which is capable of processing out automatically, after the desired dryness degree has been pre-set, and only on the basis of a simple measurement of the temperature in subsequent moments, the time needed to reach with a reasonably good accuracy the pre-set dryness degree of the clothes, while avoiding not only the inaccuracies connected with the processing of a single temperature gradient, but also the functional and construction complications brought in by the use of additional sensors, as well as the need of feeding the information concerning the type of fabrics into the machine, and using safe, reliable and inexpensive methods and means, along with readily available technologies, to reach such a purpose.

The present invention will be more clearly understood from the description which is given below by way of non-limiting example with reference to the accompanying drawings, in which:

- Figure 1 illustrates a diagram showing a typical curve of the temperature of the air in a clothes drying machine;
- Figure 2 illustrates a schematics of a neural network structure similar to the one according to the present invention;
- Figure 3 is a view of the diagram shown in Figure 1 with the sampling of the initial times and the related temperatures in a method according to the present invention.

In the following description, the term "water" will be used to indifferently mean also wash liquor and rinse water. However, such a simplification will not affect the clearness or understandability of the illustration owing to the context in which such a term is used, as anyone skilled in the art will readily appreciate along with the fact that the present invention applies to combined clothes washing and drying machines as well, for that part of their cycle and for those devices and arrangements of such machines which are devoted to or used during their drying phase alone.

With particular reference to Figure 1, which refers to a preferred embodiment of the present invention, a solution according to the present invention will be explained hereinafter, along with its operating principle.

The proposed method is based on the calculation of the drying time, as performed after the first phase of the drying cycle when steady-state temperature conditions start practically to prevail inside the machine.

Experiments that have been carried out in this connection have led to the selection of temperature of the drying air at its outlet from the drying drum as a preferable, although not exclusive parameter of the method on which such a calculation is to be based.

The typical evolution pattern of such a temperature in the course of the drying process is illustrated in Figure 1.

During the initial heating-up phase, the temperature of the air rises at a more or less quick rate, while the actual evolution is influenced by a number of prevailing factors, ie.:

- the weight and type of the clothes making up the drying load,
- the initial moisture content of the clothes,
- the structure of the machine,
- the initial temperature of both said structure and the clothes,
- power rating of the heating elements,
- air flow rate,
- heat capacity of the structure,
- etc.

By going through a sufficiently high number of drying runs in which the above cited factors are systematically changed, it has been observed that the shape of the temperature curve, although of course variable under the individual test conditions, shows a good correlation with the drying time. In particular, the final dryness conditions experimented are those commonly known as "ironing dry" and "wardrobe dry", identifying the destination of the dried clothes.

In order to make use of such an apparent correlation, a calculation algorithm has been conceived which establishes a direct quantitative connection between the profile of the temperature rise curve during the initial heating-up phase and the time needed to dry the clothes to the pre-set level.

Such an algorithm utilizes the principle of neural networks, which is known to those skilled in the art, but of which a non-exclusive example is given below for purposes of a more complete documentation.

The principles of neural networks can be found for instance in the publication "NEURALE NETZE" by Monik Koehle, ed. Springer Verlag Wien-New York, as well as in the publication "NEURAL NETWORK EXPERIMENTS ON PERSONAL COMPUTERS AND WORKSTATIONS".

THE TECHNIQUE OF NEURAL NETWORKS

As a simplified model of the manner in which the brain works the assumption has been made according to which excited neurons do in turn excite close-by neurons, and this process is repeated iteratively until a last output neuron is finally excited (see Figure 2).

For instance, the neuron A1 receives 6 inputs, combines them and sends in turn 4 outputs to the neurons B1, B2, B3, B4. The manner in which A1 combines the 3 inputs in order to form the output is given by:

$$\text{output} = \frac{1}{1+ e^{[(a_1.\text{input1}+a_2.\text{input2}+a_3.\text{input3}+a_4.\text{input4}+a_5.\text{input5})-b]}}$$

The valuableness of neural networks comes from their peculiarity according to which, through an appropriate selection of the coefficients a1, a2 ... etc., as well as b, it is possible for the behaviour of physical systems to be reproduced, ie. for the output from the input signals to be calculated much in the same way as the actual physical system would respond to said inputs.

The simulation of a physical system comes therefore down to:

- selection of the number of neuron layers;
- selection of the number of neurons per layer;
- selection of appropriate coefficients a1, a2 ... b.

This last step can anyway be automated through the use of available computational software packages that enable the coefficients a1, a2 ... b to be assessed on the basis of experimental input and related output data.

APPLICATION OF THE NEURAL NETWORK TECHNIQUE TO THE CLOTHES DRYING ALGORITHM

An automatic calculation and control device, such as for instance a microprocessor, stores the desired level of dryness in its memory and, during the first phase of the drying cycle, stores also a plurality n of temperatures T1, T2 ... Tn that are detected at regular intervals in correspondence of respective instants t1, t2 ... tn (see Fig. 3).

An algebraic function is available which, on the basis of:

- the measured temperature data,
- other previously stored parameters a1, a2, ... ak, and
- the desired degree of dryness,

is capable of calculating and delivering the drying time that is needed to reach the pre-set degree of dryiness.

Said function is obtained by using a learning algorithm according to the principles of neural networks (for instance, of the "perceptron" type) to classify in an adequately differentiated manner the possible historical data sets, by processing the respective data obtained experimentally for each machine capable of performing said process, while sequentially and methodically varying, and storing, the most significant parameters (as selected on the basis of thermodynamic considerations and fine-tuned experimentally), as referred to instant values, average values, differences of the temperature values making up the historical data set, as well as all most significant factors having an influence on the drying process, such as the amount and the type of clothes in the drying load, the room temperature and the machine temperature, the heat capacity of the machine, etc., along with the drying times as measured experimentally in correspondence of respective levels of dryness.

As compared to prior-art methods and techniques, the difference lies in the fact that, with the method according to the present invention, the concept of temperature gradient (which is the cornerstone of the afore cited patents) is dropped in favour of the concept, and the corresponding mathematical-experimental techniques, of historical sets, wherein various methods of classification of historical sets are applied in view of establishing a correlation between the results and the drying times needed.

It will be appreciated that anyone skilled in the art may be capable of identifying a number of other solutions and optimizations in the use of the afore described method by having resort to techniques and knowledges that are commonly known in the art, so that, although the invention has been described using a generally known terminology, it cannot be considered as being limited by these, since anyone skilled in the art will appreciate that a number of variations and modifications can be further made involving both construction and shape. The appended claims shall therefore be understood to include such possible modifications as anyone skilled in the art is capable of appreciating, and which do not depart from the scope and the real meaning of the present invention.

Claims

1. Method to automatically control the drying cycle in a clothes drying machine, for a multiplicity of drying loads, until the desired degree of dryness is reached, comprising the phase in which the degree of dryness to be reached at the end of the cycle is set on the machine, and said desired degree of dryness is then further processed so as the drying cycle is terminated as soon as the clothes reach said desired degree of dryness, **characterized in that** it is capable of calculating the drying time needed to reach said pre-set degree of dryness by only processing, during the initial phase of the drying cycle, a plurality of data referring to a set of initial temperatures (t1, t2 ... tn) of the clothes drying air, the corresponding instants at which said temperature values are measured, the desired degree of dryness to be reached by the clothes, and a plurality of previously stored parameters identified on the basis of a multiplicity of experimental data.

2. Method according to claim 1, **characterized in that** the temperature of said drying air is measured when the air is leaving the clothes being dried.

3. Method according to claim 1 or 2, **characterized in that** said processing is carried out by solving a function whose parameters are at least some among said initial temperatures (t1, t2, ... tn) and a plurality of fixed parameters that are characteristic of the various modalities of operation of said machine when handling different drying loads.

4. Method according to claim 3, **characterized in that** said fixed parameters (a1, a2, ... ak) are obtained by processing according to a learning algorithm the results of a plurality of experiments performed for said machine with the multiplicity of drying loads considered, which are variable at least as far as weight, type of clothes and initial moisture content.

5. Machine for drying clothes, **characterized in that** it is adapted to operate according to any of the afore cited methods and to automatically terminate the drying cycle as soon as the drying time calculated according to said method has elapsed.

6. Machine for drying clothes according to claim 5, **characterized in that** it is capable of making the information concerning the time still needed to complete the drying process available immediately at the end of the last temperature reading instant (tn) during the initial phase of the drying cycle.

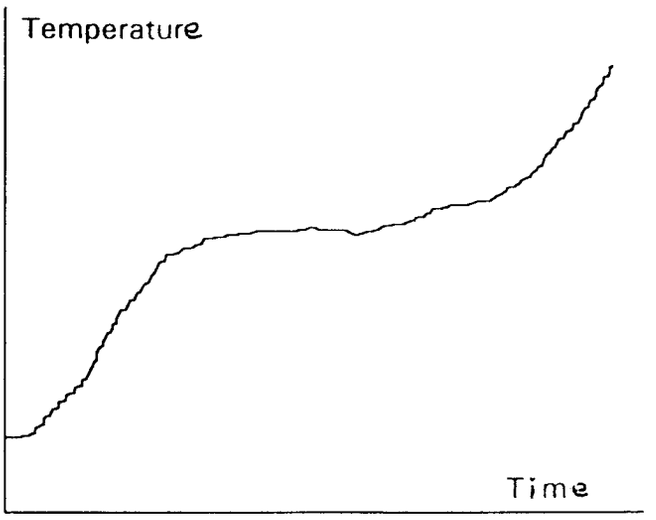

Fig. 1

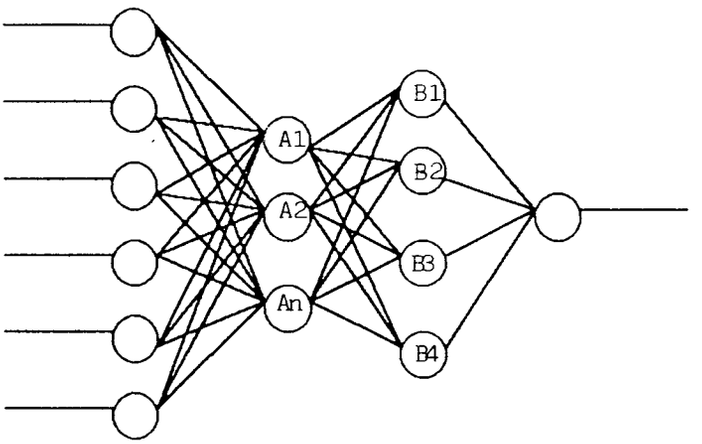

Fig. 2

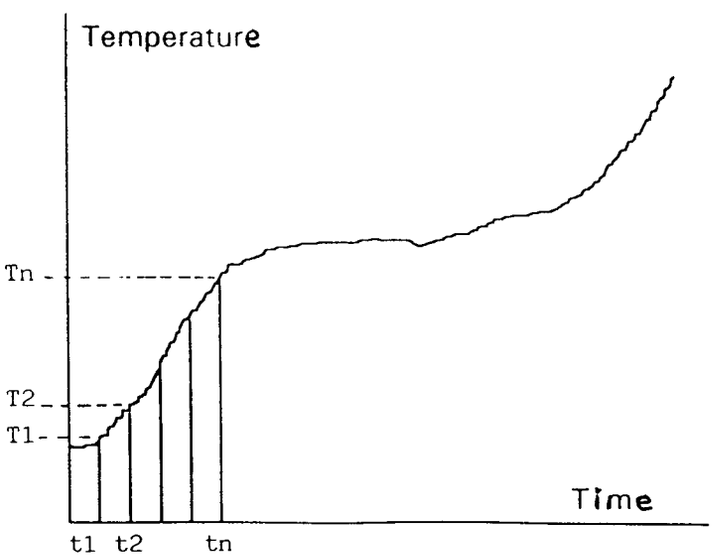

Fig. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 11 4450

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP-A-0 060 698 (T.I. DOMESTIC APPLIANCES LIMITED) * the whole document *	1-3,5,6	D06F58/28
A	DE-A-31 02 843 (MIELE & CIE GMBH) * the whole document *	1-3,5,6	
A,D	DE-A-30 30 864 (BOSCH-SIEMENS HAUSGERÄTE GMBH) * claims; figures *	1-3,5,6	
A	US-A-5 172 490 (KABUSHIKI KAISHA TOSHIBA) * the whole document *	4	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6) D06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 January 1996	Courrier, G

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
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