



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
05.02.2014 Bulletin 2014/06

(51) Int Cl.:
D06F 37/30 (2006.01) D06F 33/02 (2006.01)

(21) Application number: **12178421.9**

(22) Date of filing: **30.07.2012**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA ME

- **Civanelli, Claudio**
21025 Comerio (IT)
- **Pastore, Cristiano**
21025 Comerio (IT)
- **Moscatelli, Davide**
21025 Comerio (IT)
- **Cinili, Fabio**
21025 Comerio (IT)

(71) Applicant: **WHIRLPOOL CORPORATION**
Benton Harbor, MI 49022 (US)

(72) Inventors:

- **Colombo, Davide**
21025 Comerio (IT)
- **Parachini, Davide**
21025 Comerio (IT)

(74) Representative: **Guerci, Alessandro**
Whirlpool Europe S.r.l.
Patent Department
Viale G. Borghi 27
21025 Comerio (VA) (IT)

(54) **Method for controlling the speed of a rotating drum of a horizontal axis washing machine and washing machine using such method**

(57) A method for controlling the speed of a rotating drum of a horizontal axis washing machine comprises a step for assessing the weight of the laundry load and a

further step to determine, for the assessed load weight, a drum speed which maximizes the mechanical action to the laundry and/or a drum speed which corresponds to the highest efficiency of the motor.

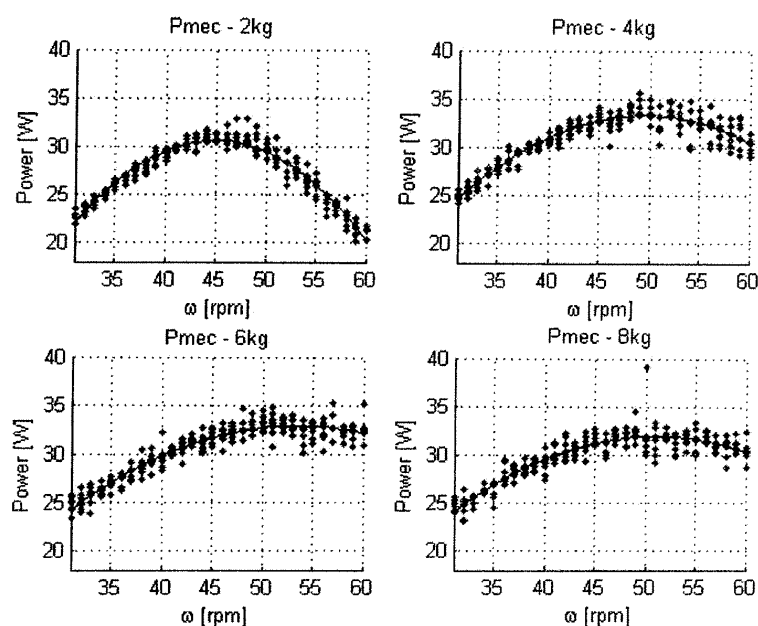


FIGURE 2

Description

[0001] The present invention relates to a method for controlling the speed of a rotating drum of a horizontal axis washing machine comprising a step in which the load of the laundry is estimated or measured. The present invention relates to a horizontal washing machine adapted to carry out such method as well. With the term "horizontal axis washing machine" we mean every appliance in which the rotating drum is mounted with a substantially horizontal axis; therefore washing machines with a slanted axis of rotation are comprised in the above definition.

[0002] Today washing machines are controlled typically with a unique speed profile for each wash cycle. JP 2004236704 discloses a washing machine in which the drum is rotated slowly for performing soaking when wash water is present in the drum, and at high speed for performing tumbling when wash water is drained from the drum.

[0003] It is well known in the art the need either to reduce the duration of the washing cycle or to increase energy efficiency of the appliance.

[0004] It is an object of the present invention to propose a method for controlling the motor of a washing machine according to which the overall cycle time can be reduced and the energy efficiency can be increased.

[0005] According to the invention, such object is reached thanks to the features listed in the appended claims.

[0006] One of the most relevant features of the method according to the invention is to increase the efficiency during the tumbling phase of the washing process in a horizontal axis washing machine by changing dynamically the reference speed of the drum.

[0007] The main benefits of the invention are a higher mechanical action and so reduced time for washing (and energy) and maximization of the motor efficiency having an equal mechanical action and time but saving energy.

[0008] The adaptive speed control has the target to consider two main metrics, i.e. the mechanical action exerted upon the load and the motor efficiency.

[0009] Further advantages and features according to the present invention will become clear from the following detailed description, with reference to the attached drawings in which:

- Figure 1 is a single base tumbling cycle typical of a horizontal axis washing machine;
- Figure 2 shows different diagrams for different loads showing how the mechanical power transferred to laundry load changes with the drum speed of rotation
- Figure 3 shows diagrams similar to figure 2 in which, for different loads, it is shown how the electrical power of the motor changes with the drum speed of rotation;
- Figure 4 shows a flow diagram of a control algorithm according to the invention;
- Figure 5 shows how the drum speed is changed vs. time when the algorithm of figure 4 is implemented;
- Figure 6 shows the speed variation of figure 5 vs. time; and
- Figure 7 is a diagram showing a comparison between a known standard washing cycle and an adaptive cycle according to the invention as far as energy consumption is concerned.

[0010] With reference to figure 1, the output of the control logic is the magnitude A of the reference speed signal of a single base tumbling cycle, where in a first part of the cycle the drum speed A is clockwise and in a second part of such cycle the speed A is counterclockwise (or vice versa).

[0011] **Error! Reference source not found.** shows the differences trend among mechanical power and tumbling speed against the load size. In a first approximation the friction of motors and washer can be considered as offset so mechanical action on laundry can be considered proportional to the mechanical power.

[0012] The mechanical power can be estimated or measured from motor in different ways. On universal motor, typically used in washers, the firing angle or the motor current can be converted to torque and then to mechanical power by using a look-up table or observer.

[0013] Depending on load size, the mechanical action trend has different shape. For example, for a full load (8 kg), the amount of mechanical action that can be generated is quite small, whatever speed you set. Otherwise, for a small load the variation of mechanical action can be very important against a little change of the rotation speed.

[0014] Figure 3 shows a similar analysis done for electrical motor power required against speed and load size. Typically the higher is the speed the higher is the efficiency of the motor. The graphs of figure 3 show curves for universal motor used in an 8 kg machine with different loads. By comparing figures 2 and 3, it is clear how the trend of electrical power is different than the trend of the mechanical power. This means that generally the speed that can be selected to optimize the mechanical action doesn't optimize the energy efficiency.

[0015] In order to maximize the cycle performance, the applicant has discovered that the following control strategy can guarantee the best performances of a horizontal axis washing machine, either in term of cycle duration or energy efficiency:

- Maximize the mechanical action with an algorithm able to find the speed with highest mechanical action.

- Obtain best compromise between mechanical action and motor efficiency

[0016] The algorithm according to the invention starts selecting an initial tumbling speed by using a predicted or calculated dry load mass and a look-up table. The look up table is obtained maximizing the following performance index:

$$\text{Performance index} = \alpha \cdot \text{mech power}(\omega) + (1 - \alpha) \cdot \text{electrical power}(\omega)$$

where:

$\alpha = 1$ will lead to a cycle that maximize the mechanical action (faster cycle)

$0 < \alpha$

< 1 will lead to a cycle to compromise mechanical action and motor efficiency (efficiency cycle)

[0017] From the example carried out by the applicant with reference to a commercial 8 kg washer, the following table of speed suggestions can be obtained:

Load Size	Mass Interval [kg]	Speed [rpm]
Small	$m \leq 3$	45
Medium	$3 < m < 6$	50
Big	$m \geq 6$	60

[0018] In order to improve the algorithm, considering the noise variation due the load estimation sensing and the process itself, it is possible to adjust the speed dynamically during the washing cycle following the algorithm shown in figure 4. A fake value is initially given to the performance index (typically 0) and to the speed variation (i.e. $\Delta\omega(0) = 3$ rpm). During every single tumbling cycle the average of mechanical and electrical power is estimated or measured and the performance index is computed according to the above formula. The value α is in relationship with the choice of the user (through a user interface) whether he/she prefers the shortest washing cycle or the lowest motor energy consumption. In this way the user can set the level of the compromise between the speed value corresponding to the highest mechanical action and to the speed value corresponding to the highest motor efficiency. Of course such α value can be also predetermined by the appliance manufacturer as a good compromise between duration of the washing cycle and energy efficiency of the motor. The performance index is compared with the one calculated at the cycle before.

[0019] If the performance index increases, the rotation speed is modified (increased or decreased) in the same way of the previous time otherwise the direction is reversed. An alternative way to adapt the cycle is given by adapting the speed following the equation below:

$$\Delta\omega(t) = \beta_m \frac{\Delta \text{mech power}(t)}{\Delta\omega(t-1)} + \beta_e \frac{\Delta \text{electrical power}(t)}{\Delta\omega(t-1)}$$

[0020] Where:

β_m, β_e are coefficients that make the two gradients comparable and that allow a tradeoff between a cycle more effective in mechanical action or more efficient in energy consumption.

In Error! Reference source not found. it is represented the magnitude of the reference speed of the tumbling phase of a washing cycle that use the adaptive control logic according to the present invention. The speed value converges quickly to a stable one (more or less 58 rpm)

In Error! Reference source not found. is shown the speed increase that the control logic forces on the reference speed on the same example of figure 5.

[0021] The benefits due to the speed variation are shown in **Error! Reference source not found..** More in details, the energy consumption of two different tests with the same configuration for all the parameters are illustrated. The first one refers to standard control logic, i.e. with a fixed tumbling speed, while the second one refers to the adaptive logic according to the invention.

[0022] If we consider a standard cycle with 3 hours long cycle there is an energy saving of about 15% between the two logics. The same benefits can be extended to time saving as well.

Claims

1. Method for controlling the speed of a rotating drum of a horizontal axis washing machine, comprising a step for assessing the weight of the laundry load, **characterized in that** it comprises a step to determine, for the assessed load weight, a drum speed which maximizes the mechanical action to the laundry and/or a drum speed which corresponds to the highest efficiency of the motor.
2. Method according to claim 1, wherein the actual drum speed is calculated as a weighted average between the speed value corresponding to the highest mechanical action and to the speed value corresponding to the highest motor efficiency.
3. Method according to claim 2, wherein the actual speed of the drum is calculated as the value which maximizes a performance index which is computed taking into consideration both the electrical power and the mechanical action.
4. Method according to claim 3, wherein the computation of said performance index is carried out according to the following formula:

Performance index = $\alpha \cdot \text{mech. power } (\omega) + (1 - \alpha) \cdot \text{electrical power } (\omega)$ where:

$\alpha = 1$ will lead to a cycle that maximize the mechanical action (faster cycle)

$0 < \alpha$

< 1 will lead to a cycle to compromise mechanical action and motor efficiency (efficiency cycle) .

5. Method according to claim 3 or 4, wherein it comprises the following steps:

- starting rotating the drum at a predetermined starting value;
- based on the assessed load of laundry, determining the mechanical power and the electrical power;
- computing said performance index;
- comparing the calculated performance index with a starting predetermined performance index or with a performance index calculated in a previous step;
- if the performance index increases, changing the drum speed in the same direction of the previous iteration, otherwise changing the direction; and
- if the performance index remains substantially the same, discontinuing drum speeds change.

6. Horizontal axis washing machine comprising a rotating drum, a motor and a control unit for driving the motor, such control unit being adapted to assess laundry load in the drum, **characterized in that** the control circuit is adapted to determine for the assessed load a drum speed corresponding to a maximized the mechanical action to the laundry and/or a drum speed corresponding to the highest efficiency of the motor.
7. Horizontal axis washing machine according to claim 6, wherein the control unit is adapted to calculate a drum speed which is a weighted average between the speed value corresponding to the highest mechanical action and to the speed value corresponding to the highest motor efficiency.
8. Horizontal axis washing machine according to claim 7, wherein a user interface is provided on which the user can set a value which sets the level of said weighted average between the speed value corresponding to the highest mechanical action and to the speed value corresponding to the highest motor efficiency.

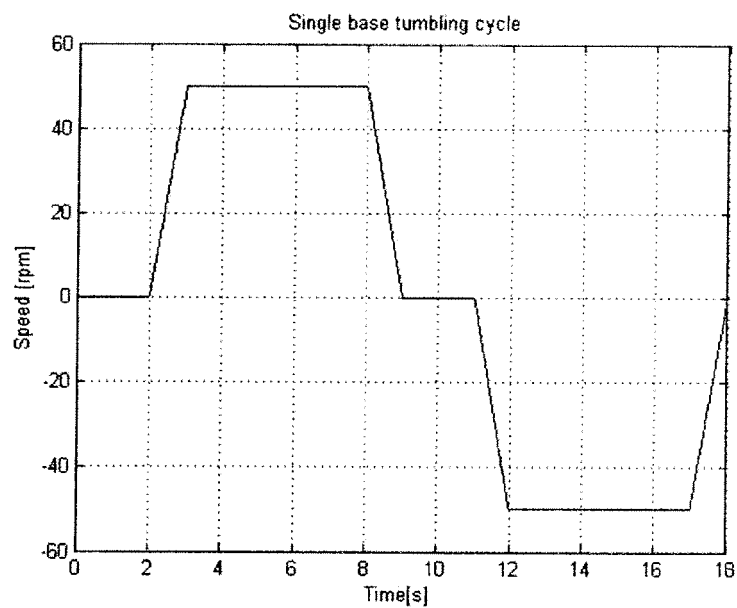


FIGURE 1

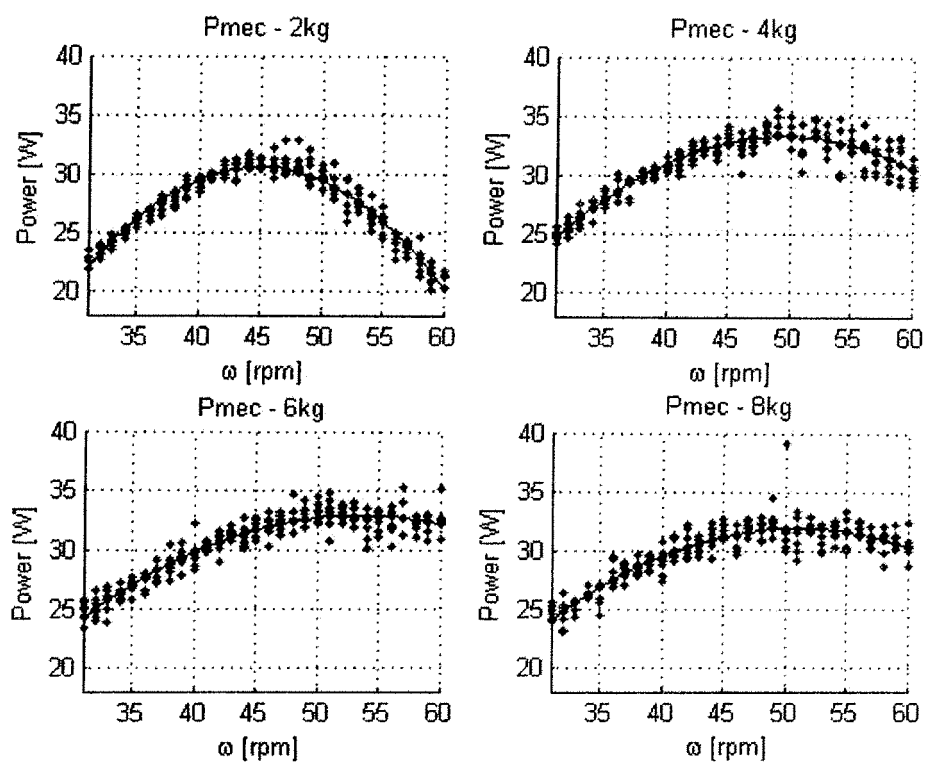


FIGURE 2

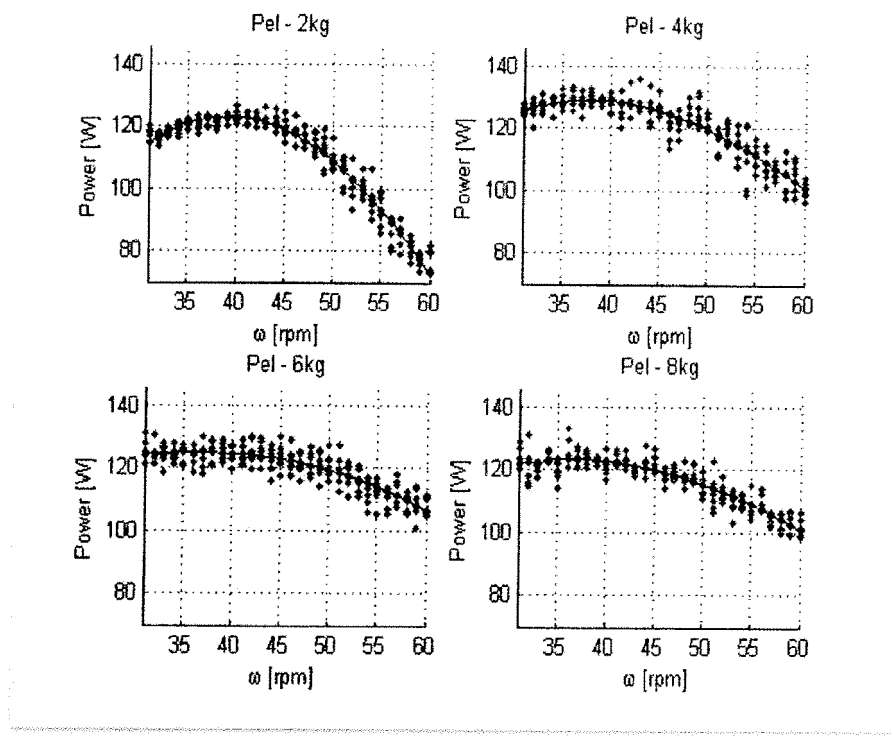
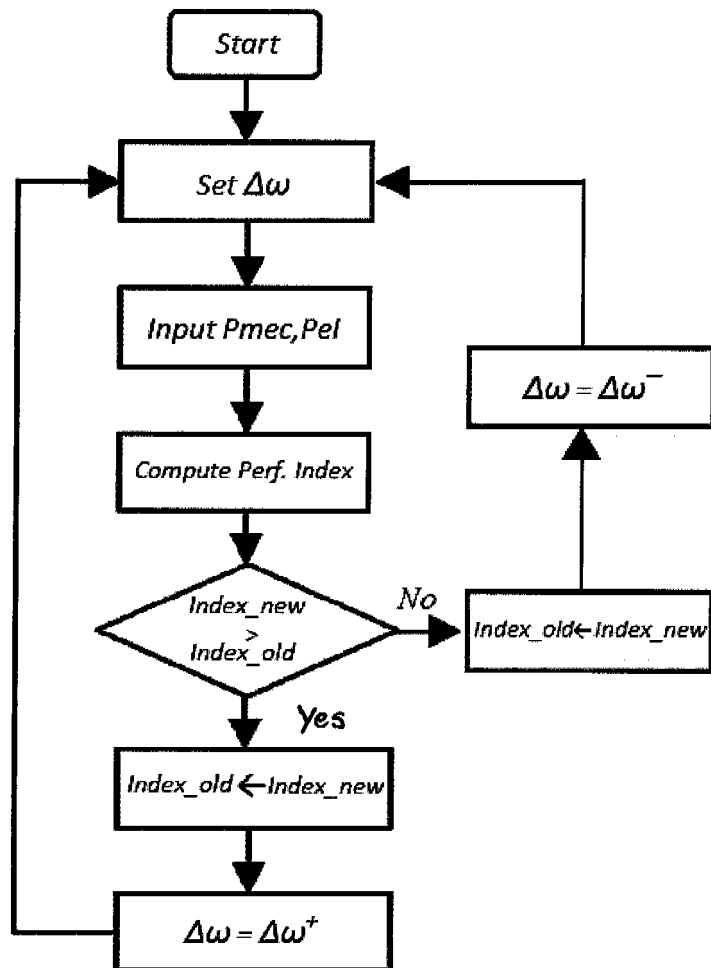


FIGURE 3

**FIGURE 4**

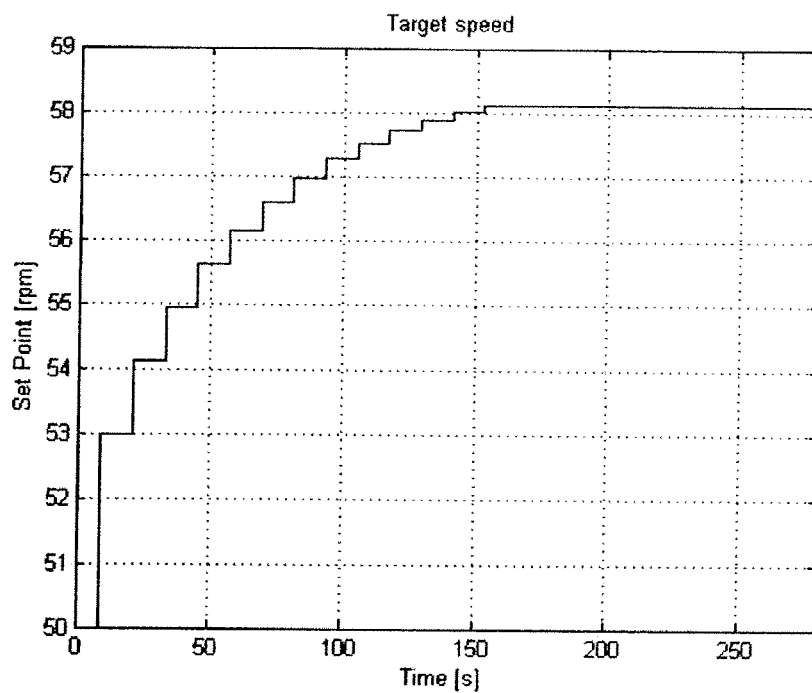


FIGURE 5

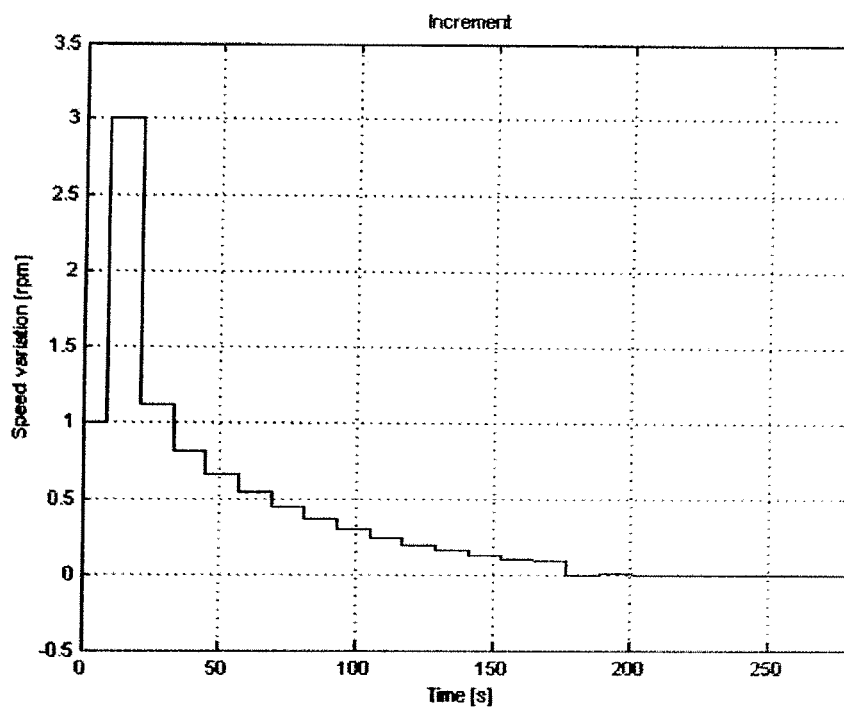


FIGURE 6

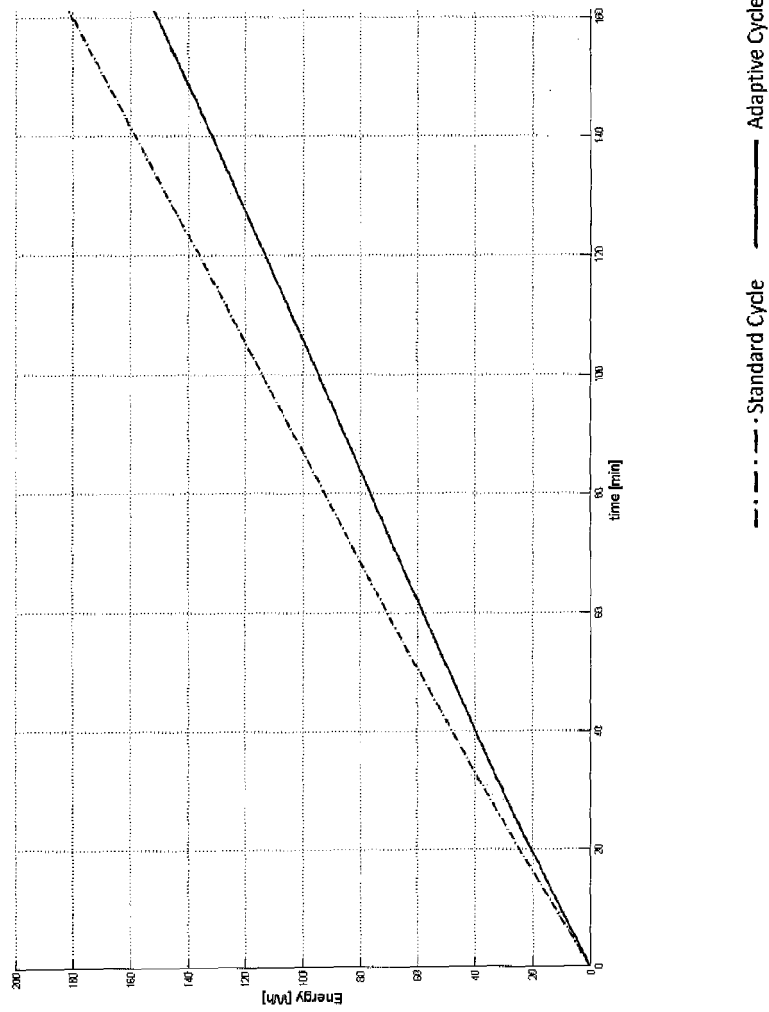


FIGURE 7



EUROPEAN SEARCH REPORT

Application Number
EP 12 17 8421

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	EP 1 441 055 B1 (LG ELECTRONICS INC [KR]) 25 March 2009 (2009-03-25) * paragraph [0022] - paragraph [0027] * * paragraph [0032] - paragraph [0033]; figures 2-4 *	1,6	INV. D06F37/30 D06F33/02
X	EP 2 080 832 A1 (ELECTROLUX HOME PROD CORP [BE]) 22 July 2009 (2009-07-22) * paragraph [0012] - paragraph [0013] * * paragraph [0016] * * paragraph [0038] - paragraph [0040]; claim 1; figures 3-5 *	1,6	
A	US 2011/016738 A1 (ASHRAFZADEH FARHAD [US] ET AL) 27 January 2011 (2011-01-27) * paragraph [0035] - paragraph [0036] * * paragraph [0045] - paragraph [0049] * * figures 5-7 *	1,6	
A	US 2008/115295 A1 (VADAKKEVEEDU KALYANAKRISHNAN [US] ET AL) 22 May 2008 (2008-05-22) * paragraph [0021] - paragraph [0024] * * paragraph [0034] - paragraph [0038] * * paragraph [0049] - paragraph [0051] * * paragraph [0078] - paragraph [0079]; figures 6,7 *	1,6	TECHNICAL FIELDS SEARCHED (IPC) D06F
A	EP 2 471 993 A1 (TOSHIBA KK [JP]; TOSHIBA CONSUMER ELECT HOLDING [JP]; TOSHIBA HOME APP) 4 July 2012 (2012-07-04) * paragraph [0025] * * paragraph [0031]; figures 17,20 *	1,6	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 17 July 2013	Examiner Fachin, Fabiano
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

2
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 12 17 8421

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

17-07-2013

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1441055	B1	25-03-2009	AT 426700 T	15-04-2009
			CN 1517475 A	04-08-2004
			EP 1441055 A1	28-07-2004
			KR 20040065668 A	23-07-2004
			RU 2262563 C1	20-10-2005
			US 2004139558 A1	22-07-2004

EP 2080832	A1	22-07-2009	AT 549448 T	15-03-2012
			EP 2080832 A1	22-07-2009
			EP 2083112 A1	29-07-2009
			RU 2009101179 A	20-07-2010

US 2011016738	A1	27-01-2011	DE 102010016454 A1	10-02-2011
			US 2011016738 A1	27-01-2011

US 2008115295	A1	22-05-2008	BR PI0704411 A	01-07-2008
			CN 101182674 A	21-05-2008
			US 2008115295 A1	22-05-2008

EP 2471993	A1	04-07-2012	CN 102482833 A	30-05-2012
			EP 2471993 A1	04-07-2012
			KR 20120037032 A	18-04-2012
			WO 2011024611 A1	03-03-2011

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2004236704 B [0002]