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Fuzzy Control Analysis with Back-EMF in Washing Machines

Min-yan DI
Hebei Normal University, Shijiazhuang Hebei 050024, China,
Tel.: 0086-0311-80787942, fax: 0086-0311-80787942
email: minyandi@126.com

Abstract

This paper puts forward a method of detecting material and quantity of the cloth in washing machine based on detection motor back EMF, not only can obtain the pulse number of reporting the information quality and quantity of the cloth, but also can collect information of pulse width, the pulse cycle, help to improve the detection accuracy of the material and quantity of the cloth. On this basis, This article also gives a specific control rules of the fuzzy control of automatic washing machine, With this fuzzy control rule table, off-line Fuzzy control response can be obtained. Finally enquiry form used to Program of assembly language, determined material and quantity and dirty degree of the cloth, to achieve the best effect of clothes washing by selecting water level, flow intensity, put the amount of detergent and washing time.

Keywords: *fuzzy control washing machine, detection load, back EMF of motor;*

1. Introduction

To make the fuzzy control rule of the washing machine. First use a variety of sensors to detect the status of washing related, as the control basis. For example, the research use the load sensor, temperature sensor, water level sensors, photoelectric sensors, and provide objective information necessary for automatic decision-making level, current intensity and washing time. The load sensor is one of the key in the fuzzy control washing machine, its main task is to detect the impedance (i.e. cloth material and cloth quantity), and so this paper mainly studies the washing machine load sensor [1-3].

2. The Traditional Load Sensor for a Washing Machine

As early as twentieth Century ago,method for measuring the material and quantity of cloth , detection of commonly used so-called dry test: put the laundry into the washing machine in water before the load test, the digital tachometer recording the motor speed, memory the transient recording of motor, electronic counter records waveform processing after analyzed. Logic analyzes the change of state. The operating state parameters are determined according to the test results of washing machine. But there will be various influences on the load test in the detection process [4-5]:

(1) Effect of motor speed: motor speed have a great effect on test. As motor speed increases, the load tests data raise, presents a nonlinear relationship. The results also show that in the low speed to a certain value, the detection method will be failed. This is the main influence of driving speed stabilization circuit.

(2) Effects of starting and braking characteristics: riseing load characteristics have a good performance in single phase capacitor motor, but for the influence of series excited motor itself characteristics and peripheral driving circuit effects appear messy and rules are hard to find, especially in the light load and heavy load conditions is particularly prominent, It is more difficult to distinguishing the characteristics when there is clothes friction and a light load.

(3) Affect of the mechanical properties: clothing and room body friction and drive transmission system have a relatively large impact on the test, the former changes along with the different products, the latter have the effect on when the clothes to a certain extent. The two should be considered in the test method.

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(4) Supply voltage effects: the power supply voltage have a great effect on the test results, the test data change along with the voltage fluctuation.

In view of the above all sorts of effects and complex sensor circuit (mainly by the drive circuit, steady speed circuit, measuring circuit and digital processing unit) makes the measuring speed method load sensor of high cost and the testing accuracy not high, therefore, it is replaced by the measured EMF method.

3. The Method of Measurement Load Based on Detection Motor Back Emf

After adding a small amount of water to the washing machine, the motor runs with load for a short time. When the power supply is cut off suddenly, the motor rotation will remain for a short period of time due to the inertia effect. At this point, the rotor remanence will cut stator and then induce potential, this potential can be taken out of the motor winding. Under the damping effect of clothing, motor speed falls and back EMF also increases with time and finally disappears showing a trend of damping oscillation. The attenuation and oscillation characteristics of back EMF signal are related to the quantity and material of the washed clothes. In general, the more clothes are, the faster the counter potential attenuation will be [6-8].

3.1. The General Method of Back EMF Detection

We achieve the result of load testing by detecting the motor's back EMF, and the motor back EMF voltage is much more larger than single chip microcomputer. So we must use isolation but not direct sampling. Using a linear photoelectric coupler can isolate high voltage and interference, and obtain satisfactory detection signal. So we turn the back EMF AC signal after a power outage to DC signal by half wave rectifier, and to pulse signal after photoelectric isolation and shaping amplification, then we send them to the microcounter to measure the pulse number (as shown in Figure 1).

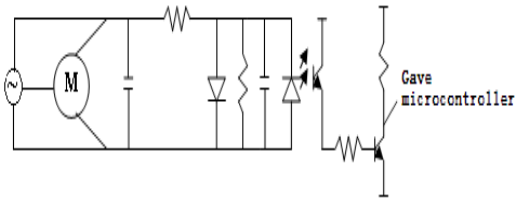

Figure 1. The Circuit of Pulse Detection

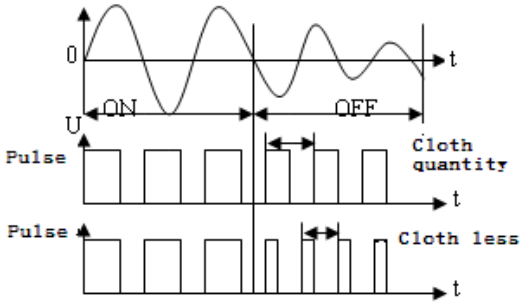

Figure 2. The Analysis of Cloth Quantity

According to the collected number of pulses, we can determine the amount of cloth quantity. We consider that the pulse numer is lesser, the laundry is more, and vice versa(as shown in Figure 2).

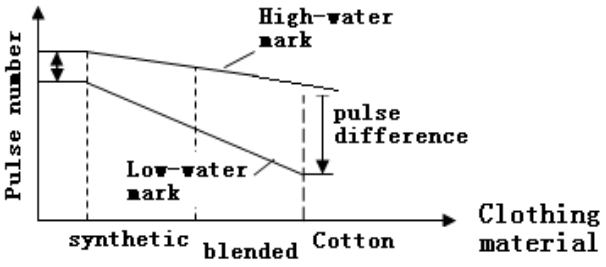

Figure 3. The Analysis of Cloth Material

As for the cloth material, it can be divided into cotton, blended, synthetic fiber this three categories. Cotton and synthetic fiber clothes have different damping under different water levels. Due to the synthetic fiber clothes' sensitive degree to water level is not as good as cotton clothes, so we can judge the garment material by shutting off the motor and measuring the D-value of pulse number under different water level. The bigger the pulse number is, more likely the cloth is cotton. While the smaller the pulse number is, more likely the cloth is synthetic fiber (as shown in Figure 3).

3.2 The Improved Method of Back EMF Detection

From theoretical analysis and experimental observation, we find that this method is one-sided for it only uses the pulse number information, and its ability to distinguish the cloth material is not high, and its dispersion is relatively large. Making use of a new kind of cloth fabric quantity interface circuit(as shown in Figure 4), we can not only detect the number of pulses, but also collect pulse width, pulse cycle (frequency). We can see the attenual oscillation characteristics of back EMF ideally and comprehensively. In the condition of the same number of pulse, we can further distinguish between cloth farbic and cloth quantity, then improve the detection accuracy.

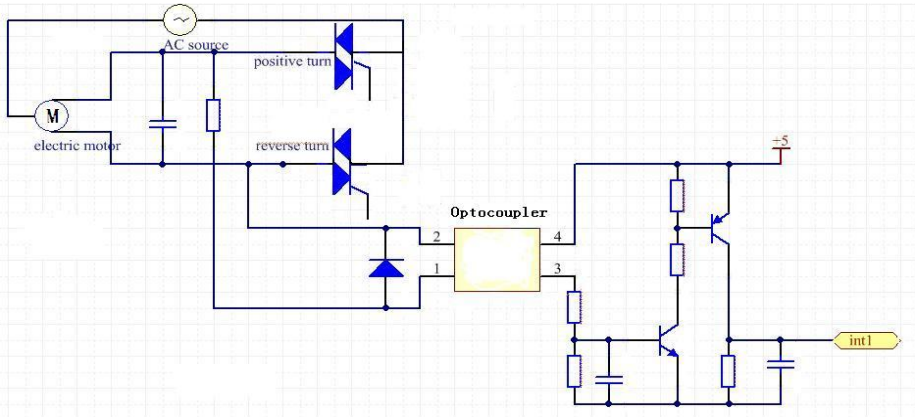

Figure 4. The Circuit Principle Diagram of Load Detection

3.2.1. The Testing of Cloth Quantity

After the clothes are put into the laundry, we drain and start the motor, using th pulse voltage which is on for 0.3s and off for 0.7s to drive the motor for 32s. In this process, we use a photoelectric couple to send and receive pulses for measuring the rotational inertia circle number when the roulette are shut off. At this point, the clothing is much more, the rotation time is shorter, the pulse number is lesser. More is the opposite.

Count Pulse and Clothing Weight's Relation Curve has Shown in Figure 5.

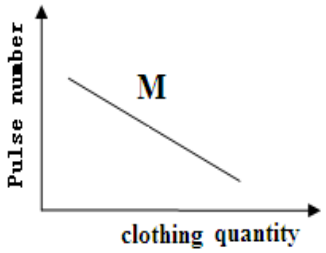

Figure 5. Analysis of Clothing Quantity

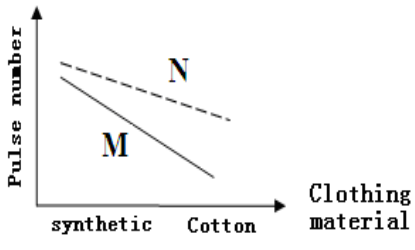

Figure 6. The Discrimination Curve of Cotton and Synthetic Fiber Products

3.2.2. The Testing of Cloth Material

The following includes the distinguish between cotton and synthetic fiber products as well as the difference between soft fabric and thick cloth. Definite methods are as follows:

Based on the test load, we drain away little water, and use the pulse water which is on for 0.3s and off for 0.7s to actuate the motor for 32s, then record the pulse number N; If the detection pulse load number is M, then we can determine the general situation of material distribution depending on the value of M-N. The cotton is much more, the value of M-N is larger, the smaller is the opposite.

When the proportion of cotton and synthetic products is different, the twice curve of the measured pulse number has shown in Figure 6.

Cotton goods are the same, but for the hard and thick cloth towel like denim and the soft fabric, the washing methods are different. How to distinguish? It needs the water level sensor to measure. The specific method is: After the pulse drive for 32s by water injection, we compare the change of water quantity.If the variation is small, it proves the cloth is easy to absorb water and tends to be towel cloth, or maybe denim fabric. Figure 7 is the water-level curve in both cases.

Soft fabric or hard thick cloth also can be identified by the waveform changes of analog current (as shown in Figure 8).

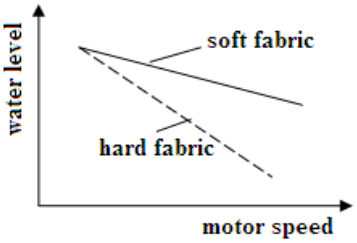

Figure 7. The Water Level Curve of Soft Fabric and Hard Thick Cloth

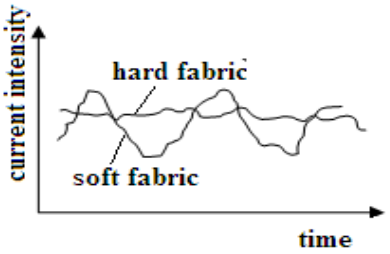

Figure 8. The Comparison of Two Typical Current Waveform in Different Hardness Cloth

4. The Design of Software and Hardware in Fuzzy Control Washing Machine

Fuzzy control washing machine refers to the washing machines judge the weights, the texture and the degree of pollution of the clothes through sensors, to automatically determine the water level of high and low, the dosage of detergent, temperature and water flow intensity, and determine the optimum cleaning sequence. As a result of the control object of the washing process is difficult to use accurate mathematical model to describe, so the traditional control method is difficult to obtain ideal cleaning effect, while the fuzzy control method can well solve the problem. In the process of washing clothing, how much of the clothes, fabrics such as hardness and softness are fuzzy, so at first, we must do a lot of experiments, conclude the artificial washing method, thus forming the fuzzy control rules. According to the information received from the sensor, the washing machine determines how much of the clothes, hardness and smudgy degree of the fabric, and refers to a fuzzy decision, thus, finishes water injection strength, washing time, the flow strength, washing way, dehydration time, drainage, etc, all functions and automatically completes such as, automatically complete the "water", "washing", " draining", "dehydration" and other functions.

4.1. Hardware Design of Fuzzy Control Washing Machine

Fuzzy control principle diagram of the intelligent washing machine refers to Figure 9, it is a multiple input and multiple output control system. Multiple input includes the water temperature, water level, the light transmittance of water and the test data of motor's rotational properties after downtime. The data accept fuzzy processing after input to the control system, the system according to the processing results and the control rules summarized by manual washing, carries on fuzzy control operation, obtains the control decision, and control the output by controlling the actuators. During the process, the system uses the test data of water

temperature and the light transmittance of water as basis to analyze and judge the dissolution condition of water on detergent and smudgy degree of the clothing, determines the amount of detergent and washing time. It uses the inertia test data of the washing motor in low running speed as the basis to analyze and judge the material material and the amount of the clothing, determines the amount of water supply and the water flow mode when washing. The latter achieves the process by controlling the motor's speed and its positive and negative operation. In addition, the system also adopts testing water level to ensure automatic water supply as the predefined level. By testing the light transmittance of water when cleaning (i.e., rinse), the system judges the clear condition of water to make sure the rinse process is end, switches to dewatering operation automatically [9-11].

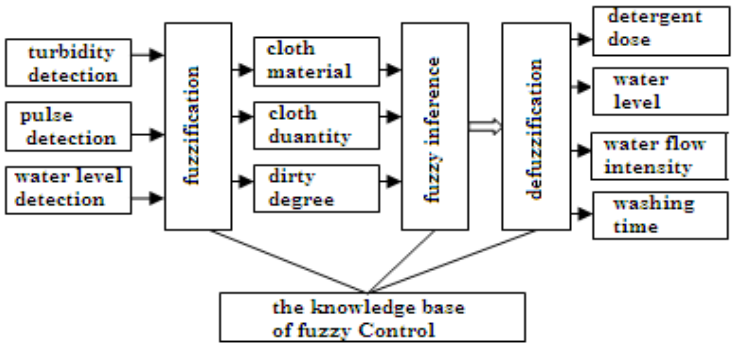

Figure 9. The Fuzzy Control Principle Diagram of the Intelligent Washing Machine

4.2. Software Design of Fuzzy Rule Wareroom

There are mainly three input variables of fuzzy control washing machine: the material material of cloth, the amount of cloth, smudgy degree; There are mainly four output variables: the level of the washing machine, washing time, temperature and detergent dose, so it is a 3 input 4 output structure. Input and output variables have respectively several kinds of states:

a) The Input

Cloth quantity: more, many, lest, rarely (discourse domain is 0-25 kg).

Cloth material: cotton, blending, synthetic fiber; (discourse domain is 1% - 100% cotton content).

Smudgy degree: very dirty, generally dirty, not too dirty. (after quantization, the discourse domain is 0-100).

b) The Output

Washing time: short, shorter, middling, long, longer;

Washing dose; rarely, less, many, more, most;

Water-flow strength: weak, medium and strong;

Water level: very low, low, high, very high.

The building of a fuzzy controller rule form and fuzzy inference rule table is based on the expert knowledge and a manual operator's long-term experience accumulation; it is a language of representation reasoning based on intuition. Usually it is connected by a series of words, taking the washing process has three main fuzzy inference antecedent and four fuzzy reasoning into account, using IF-THEN rules, and its forms of expression for:

IF (the amount of clothing) IS (the amount of clothing of a certain linguistic value) and (the material material of clothing) IS (the material material of a certain linguistic value) and (smudgy degree) IS (smudgy degree of a certain linguistic value).

THEN (water level) IS (water level of a certain linguistic value) and (water flow intensity) IS (water flow intensity of a certain linguistic value) and (washing time) IS (washing time of a certain linguistic value)and (washing dose) IS (washing dose of a certain linguistic value).

In order to represent fuzzy rules concisely, we use digital to stand for the fuzzy control output. For example: washing time (very short, short, medium, long, very long) = (1, 2, 3, 4, 5),

the method of the remaining 3 output are similar to this, when the output domains are 3, they should be represented by 3 numbers, As shown in Table 1:

Table 1. Output (digital representation)

Output(digital representation)	1	2	3	4	5
washing time	short	shorter	middle	long	longer
washing dose	rarely	less	many	more	most
water-flow intensity	week	medium	strong	--	--
water level	very low	low	high	very high	--

According to the experts' experience and combining with the actual situation of washing clothes, the fuzzy control rules can be obtained as shown in Table 2. The fuzzy rules are represented by four digits, the first digit is the height of the water level, the second is the flow intensity, the third is the amount of detergent, fourth is the washing time, such as "4355"means high water, strong water flow, many detergent, long time washing 'control way.

Table 2. Fuzzy Control Rule Table of Full-automatic Machine

cloth cloth material	cloth quantity	very dirty	generally dirty	not too dirty
synthetic fiber	more	4355	4234	4223
	many	3244	3233	3222
	lest	2233	2222	2111
	rarely	1123	1122	1111
blending	more	4355	4334	4224
	many	3345	3234	3223
	lest	2234	2223	2111
	rarely	1223	1122	1111
cotton	more	4355	4334	4324
	many	3345	3234	3223
	lest	2334	2234	2212
	rarely	1223	1222	1111

Using the fuzzy control rules table,we can get the fazzy control response table offline. Finally, we use the assembly language look-up table procedures to determine appropriate water level, water stream, detergent quantity and washing time in the corresponding cloth quantity,cloth material and dirty degree conditions to achieve the best cloth washing effects.

5. Conclusion

The counter electromotive force detection method of cloth quantity and material in this paper can not only get the information of cloth material and quantity, but also can collect comprehensive information of pulse width and cycle.It helps improve the measure precision of cloth quantity and material, and provides more objective basis to best decisions of water level,water tempreture, water flow intensity and washing dose. Based on it,we have offered the specific controlling regulation of automatic washing machine which is fuzzy-cotrolled. Automatic washing machine of fuzzy control greatly reduces the dependence on artifical catharsis experience, which saves time, worry, water, electricity and improves washing rate and intelligent degree comprehensively.

Acknowledgements

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