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Research Article

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Health diagnosis methods of automobile starter battery

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ABSTRACT

This paper discusses the comprehensive detection of the open circuit voltage of automobile battery as well as discharge current, final voltage and environment temperature of the battery. Then it calculates the electromotive force, internal resistance, cold cranking ampere and charging capacity of the battery under 25 ℃, and demonstrates through thorough analysis of automobile starter battery failure mechanism the characteristics of various states of battery, including open circuit, single circuit, dead short circuit, vulcanization and performance degradation. Based on the analysis, this paper proposes the health diagnosis scheme of automobile starter battery, and for practical purpose, integrates health diagnosis with emergency ignition function and develops the emergency ignition apparatus of automobile starter battery.

Key words: Automobile starter battery; failure mechanism; health diagnosis; emergency ignition apparatus

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INTRODUCTION

At the start of vehicle, the engine, from non-spinning to idle running, normally requires a strong current of 300A lasting for 3-5s. In winter, the starting current is supposed to rise to 500-600A or higher [1].Moreover, the electronic equipment on the vehicle also consumes electric energy even when the vehicle stays motionless, which is called slip of electricity. Long time of such phenomenon may lead to the loss of capacity, and a long-term loss will cause electrolyte crystallization, also known as vulcanization, leading to the performance degradation of the battery. Severe vulcanization can also lead to the problems such as the battery is unable to be charged or immediate full charge and immediate running out. It is known that the high quality of starter battery is the basis for the good performance of the vehicle. Therefore, it is of great practicability and application value to study health diagnosis of automobile battery and to develop special instruments for automobile battery health diagnosis.

2. PERFORMANCE TEST AND HEALTH DIAGNOSIS OF BATTERY AND AN OVERVIEW OF THE DEVELOPMENT OF EMERGENCY IGNITION APPARATUS

It has long been a challenge to make judgment on the condition of on-board battery. Scholars and engineers from home and abroad have conducted a large number of researches and experiments and made great progress. Literature [2] summarizes the present studies on prediction of the remaining capacity of battery, and proposes a scheme of online prediction. Literature [3] makes comparative analysis on current measuring methods of the internal resistance of the battery cell of DC system battery, including the use of densimetry, open circuit voltage, DC discharge and alternating current, and points out their advantages and disadvantages. It also proposes a new measuring method: AC variable frequency method, which can be measured online. Literature [4] brings up a method of AH measurement, which can easily calculate real-time remaining capacity according to the rated capacity of battery and the monitoring of the discharge current. Suppose the load is stable, then the time of power supply can be converted. Literature [5] proposes a method to measure capacity by voltage. By measuring open circuit voltage and load voltage, it can suggest the lack of capacity when these two figures decrease. Open circuit voltage has better corresponding relationships with capacity, but the measurement of it should keep for more than 2h when battery is not used. Literature [6] uses AH measurement-Peukert Formula- Open circuit voltage as the basic algorithm and develops the battery management system. Meanwhile it discusses the influence of temperature, self discharge, cycle life on the remaining capacity of lead-acid cell. Literature [7] proposes the variable current combination measurement to decide the electromotive force and internal resistance, and adopts AH measurement to obtain battery reserve. Then it sets up the neural network model to decide the non-linear relationship between electromotive force, internal resistance and battery reserve. Last, the battery reserve is decided by electromotive force and internal resistance, avoiding the problem of traditional AH measurement that it cannot work without knowing the initial state. This paper proposes a comprehensive measurement of the open circuit voltage of the automobile battery, the final voltage U_2 of discharge current I_{dechr} at 5s, and environment temperature t_{AT}. Based on the national standard implemented in 2005 to "start the application of the technical condition, varieties and standards of lead acid battery", it converts the electromotive force E, internal resistance r, cold cranking ampere $I_{-18℃}$ and load capacity （SOC）, and through the deep analysis of automobile starter battery failure mechanism demonstrates the characteristics of various states of battery, including open circuit, single circuit, dead short circuit, vulcanization and performance degradation and forms the scheme of health diagnosis for starter battery. Meanwhile, considering the safety and convenience of vehicles at emergency of unable to start, it combines the emergency ignition function with battery health diagnosis as a complete instrument.

3. COMMON FAULT OF AUTOMOBILE BATTERY

3.1 Open circuit of battery

Failure cause:

1) dry joint during battery assembly
2) heavy tossing during the use
3) change of temperature due to climate alternation and repeated charge-discharge lead to severe deformation and falling off of the positive plant type plate.

Failure phenomenon:

Capacity of battery reduces to zero; internal resistance is extremely large; cold cranking ampere is zero.

3.2 vulcanization of battery

Failure cause

1) long time of undercharge or storage in discharging or half-discharging state lead to the precipitation of lead sulfate from electrolyte.
2) low liquid level of electrolyte leads to the oxidation of the top of polar plate exposed to air.
3) high density of the electrolyte or impurity, or rapid temperature change.

Failure phenomenon:

Reduced battery capacity and charging time; faster overheat of battery; unable to charge when vulcanization is too severe.

3.3 Burn-in of the battery

Failure cause:

1) excessive discharge leads to the weakened battery activity.
2) being polluted by contaminants (eg. hydrochloric acid, sea water, organic acid)
3) charging in over-high or over-low temperature or the heat produced during charging cause the changes within the battery.
4) too much current in both ends of the battery.

Failure phenomenon:

Reduced battery capacity and increased internal resistance.

3.4 Battery single short circuit

Failure cause:

1) polar plate is corrupted, leading to the contact of both polars.
2) too much sediment in the bottom of battery case leads to short circuit.

Failure phenomenon:

Voltage of battery appears to decrease by single voltage.

3.5 short circuit of battery

Failure cause:

1) electrolyte overfall, rainwater invasion or external force cause the electrical contact of positive and negative

electrodes.
2) the corruption of polar plates in multi-cell battery causes the contact of positive and negative polar plates. Common reasons for this include: 1. overcharge of the battery or overheat during charging make active substances peel off; 2. discharging and charging with heavy current deforms the polar plates, leads to severe peeling off of active substances and too much sediment in the bottom of battery case, and gradually develops into multiple short circuit.
Failure phenomenon:
Extremely low voltage, even zero.

4. AUTOMOBILE BATTERY HEALTH DIAGNOSIS PLAN

Chapter 2 in this paper deeply analyzes the automobile starter battery failure mechanism, demonstrates the characteristics of various states of battery, including open circuit, single circuit, dead short circuit, vulcanization and performance degradation, and forms a series of schemes on automobile starter battery health diagnosis, as is shown in diagram 1.

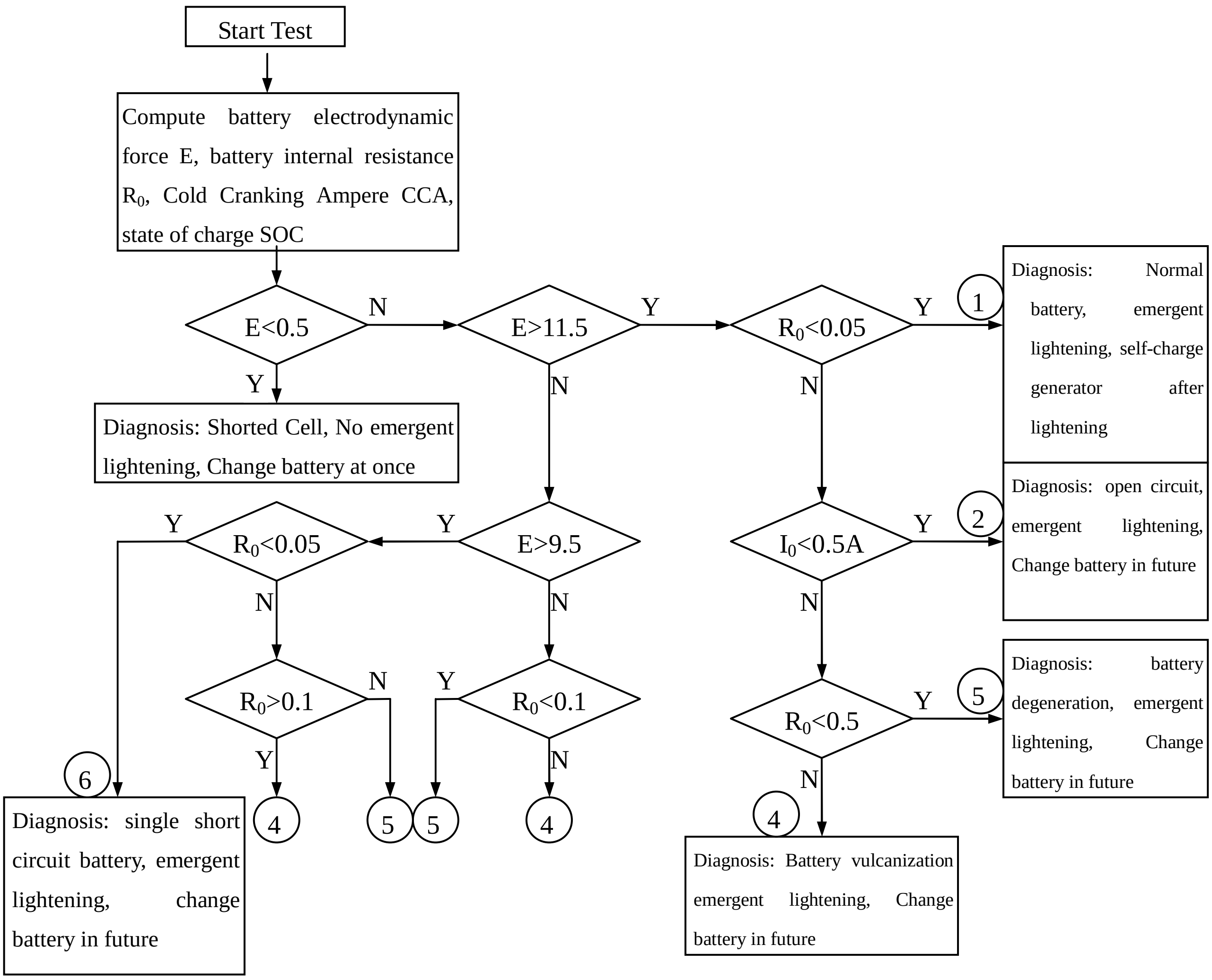

Fig. 1: Block diagram of the auto mobile starter battery health diagnosis

5. DIAGNOSIS AND SCHEMATIC WIRING AND TESTING OF THE EMERGENCY IGNITION APPARATUS

5.1 Diagnosis and schematic wiring of the emergency ignition apparatus

The schematic wiring of automobile starter battery health diagnosis and emergency ignition apparatus is shown in figure 2. Inside the virtual box are the fundamental parts and schematic wiring of the device. 1 is the smallest microcontroller system for testing, diagnosis and emergent ignition control. 2 stands for the keyboard and its interface circuit, 3 the liquid crystal display with its interface circuit, 4 the working and starting power source, K1 the working power switch, K2 the electric switch for short discharge in testing, K3 the switch for emergent ignition control, R the resistance for short discharge, 5 the anode wire for emergent ignition, 6 the annunciator wire for battery voltage testing, 7 the anode wire for discharge testing, 8 the annunciator wire for discharge current testing, 9 the signal wire for discharge and the cathode wire for emergent ignition, 10 pending-test battery, 11 the anode end for 10, 12 the cathode end for 10, 13 the temperature sensor, 14 the signal wire of 13.

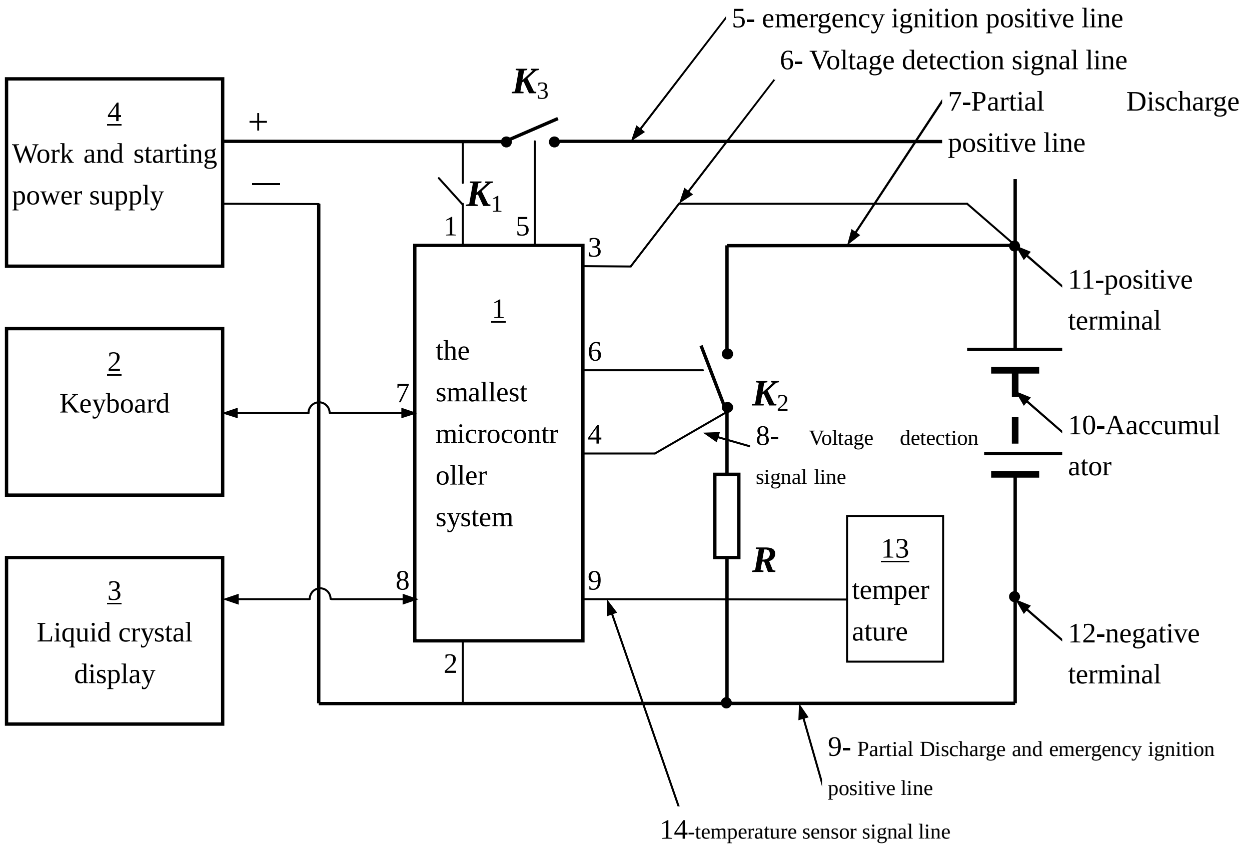

Fig. 2: Schematic wiring diagram of the device for health diagnosis of automobile starter battery and emergency

Its wiring principle is such: the anode of the working and starting power source 4 is connected to the port 1 and 2 of the smallest microcontroller system 1 through the working power switch K1 in order to supply power to 1. The keyboard 2 is connected to port 7 of 1 for order entry. The liquid crystal display 3 is connected to port 8 of 1 to display the operation information, testing parameters and diagnosis results. The anode end 11 of the pending-test battery 10 is connected to one port of the electric switch K2 of discharge circuit by an electric clip with a sheathing, the other end of which is connected to the discharge resistance R. The other end of R is connected to the cathode end 12 for 10 through the signal wire for discharge and the cathode wire for emergent ignition 9. Meanwhile, the anode end 11 of the pending-test battery joins up with port 3 of system 1 through the annunciator wire for battery voltage testing 6, so that the open circuit voltage of 10 and the cut-off voltage of short discharge can be detected. Wire 8 drawn from the joint of the electric switch K2 and R is connected to port 4 of 1 to be used to test the discharging current of the pending-test battery. During the testing, the system controls K2 through port 6 to give short discharge. The anode of the battery is connected to the switch for emergent ignition control K3 by the anode wire 5 and the electric clip with sheathing. The other end of K3 is connected to the anode of the power source 4, while the cathode end 12 of the battery to the cathode of the source through the signal wire 9, forming an emergent ignition circuit. When the device needs emergent ignition, the system controls the switch K3 through 5, closes the emergent ignition circuit and provides the ignition current.

5.1 Diagnosis and testing of emergency ignition apparatus

The main steps for the diagnosis and testing of emergency ignition apparatus:

Connect the discharge circuit wire and the testing signal wire between the apparatus and the pending-test battery.

Turn off the working power switch, initialize every device unit and wait for the diagnosis and testing order entry in the keyboard. When the smallest microcontroller system detects any order, do the following steps:

Test the open circuit voltage U0 of port of the pending-test battery;
Close switch K2, connect the short discharge circuit. Test its discharge current Idechr, the cut-off voltage U2 and the ambient temperature tAT;

Measure internal resistance R_0 of the automatic battery, Cold Cranking Ampere and state of charge. The basis of the measurement is as follows:

1) internal resistance R_0 of the automatic battery
The different of restoring voltage and cut-off voltage of the battery to be divided by discharge current, that is:

$$R_0 = (U_0\text{-}U_2)/I_{dechr} \quad (1)$$

R_0 =the internal resistance of the battery when the discharge current is I_{dechr} .

The restoring voltage when the battery stops discharging here is considered to be its open circuit voltage U_0 because normally a car would stop working for several hours after the first use.

U_2 =cut-off voltage after battery short discharge when the current is I_{dechr}

I_{dechr} =discharge current, here is 15A in this apparatus.

2) Cold Cranking Ampere (CCA).
Cold Cranking Ampere is a important quality standard measuring the cranking ability under cold environment. The definition is: a full-charged, 12V battery, under -18℃(or 0℉) gives High Intensity Discharge for 9 seconds with a voltage not lower than 9V. After 60 seconds, its voltage still remains no lower than 8.4V. The biggest discharge current is CCA. CCA aims to measure discharge ability of the battery to ensure a reliable and adequate power supply when the car revs up. It is necessary for China's car industry which is to embrace the international standards to apply CCA to regulate the test for cold cranking of the engine and teh choice of the battery. The measuring method is to detect the instant discharge current of the battery:

$$I_s = \frac{U_2}{R_0} \quad (2)$$

Then, adjust the temperature, calculate CCA I_s（A）under -18℃(or 0℉) and compare with the international standard to see whether it meets the standard.

3) State of charge
Based on the relationship between the open circuit voltage and state of charge of the car battery announced by Panasonic, SOC can be calculated by measuring the voltage U0. Or what still can be used is the relationship announced by the Canadian Testing Authority Cadex laboratory. SOC can be calculated by referring to CCA.

To conclude, by testing the open circuit voltage U0 of the battery when the car revs up, the discharge current I_{dechr} , the cut-off voltage U2 and the ambient temperature of the battery tAT, four important parameters illustrating the battery capability can be measured: electrodynamic force of automobile battery (E), the internal resistance (R_0), state of charge and CCA.

CONCLUSION

The high quality of starter battery is the basis for the good performance of the vehicle. It is important for a good maintenance of automobile battery and a smooth starting of automobiles to analyze health diagnosis of automobile battery, rapid diagnosis at emergency such as unable to start, and the method for vehicles to start at emergency. The development of special instrument for automobile battery health diagnosis and emergent start is also of great value. This paper discusses the comprehensive detection of the open circuit voltage of automobile battery as well as discharge current, final voltage and environment temperature of the battery. Then it calculates the electromotive force, internal resistance, cold cranking ampere and charging capacity of the battery, regarding them as 4 important evaluation indicators of battery performance. Moreover, through the analysis of automobile starter battery failure mechanism, it illustrates the characteristics of various states of battery, including open circuit, single circuit, dead short circuit, vulcanization and performance degradation, and proposes the health diagnosis scheme of automobile starter battery. For practical purpose, it considers the safety and convenience of vehicles at emergency of unable to start, and combines the emergency ignition function with battery health diagnosis as a complete instrument.

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