Implementation of an Automatic Checking Machine for Battery Welding Condition

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Abstract. The common automobile battery is composed of series connection of six units of battery chargers, with the tab welded between each battery charger for a purpose of connection. Thus the satisfactory welding point will be closely related to the lifetime of the battery. If the welding point is not solid enough, it will produce high resistance and heat in welding point upon numerous current discharge and charge, thus leading to a breakage of the welding point and causing damage to battery. This essay aims to implement a checking machine for battery welding condition. This machine based on a microprocessor as the core of control by combining a direct current power supply to measure the internal resistance of welding point of the battery so that the condition of the welding point can be judged. Upon the signal of inner resistance goes through an amplifier and then a buffer circuit, this analog signal will be converted into a digital signal and then be conveyed to the microprocessor. Finally, the configuration is displayed by an LED, which also reveals the results of measurement upon the comparison of the signal and a setup value. In the meanwhile the relay contact can be used to notify the PLC of the auto wire to show the condition of the battery, while RS485 or RS232 can be used to link with computer to record the welding condition of the battery.

Keywords: Battery welding condition checking, large current charge and discharge, microprocessor.

1. Introduction

A storage battery generally includes a plurality of electrode plates [1, 2], which are immersed in an electrolytic solution and interconnected sequentially in series. The series connections among the electrode plates are accomplished by soldering adjacent pairs of soldering lugs of the storage battery. If the soldering points are not firm, failure of the series connections is likely to occur. Moreover, in case there is air trapped in a soldering point, breaking of the soldering point is likely to occur when a large electric current passes there through. Furthermore, if government promote electric motor car for environmental protection someday, it is more important whether the pad is soldered well under the charging and discharging of large electric current [5-7]. Therefore, it is necessary to find ways to determine the quality of soldering points so as to ensure the quality of a storage battery product. In this study, we invented a device for inspecting a soldering point in a storage battery which can measure the inside resistance of the battery pad. In order to judge whether pad is good, the device can provide inspection results for storage by an external processing device.

In general, lead-acid batteries have pasted plate anodes employing lead as the electrode material and the electrode surface is covered with a checkerboard grid of brown PbO_2. The thin plates filled with active matter yield high output power. The PbO_2 used in batteries is formed by bonding fine particles of lead oxide. These fine particles ensure a large area of contact with the electrolyte, which reduces the battery's internal resistance. The cathode plate is produced by mixing lead with dilute sulfuric acid and a small quantity of additives to form a paste-like material. Cathode plates may also made from soft, porous, spongy pure lead. The gray paste is applied to a lead alloy grid, and allowed to cure and dry to form an unfinished cathode plate. A porous separator made of insulating material is inserted between the anode plate and cathode plate. The anode and cathode plates must be parallel and as close as possible, but may not be in contact. When the anode and cathode plates are arranged in an alternating arrangement, the tabs on the electrode plates are connected with soldered lead alloy straps, forming the anode and cathode elements shown in Figures 1 and 2. The alternating arrangement of anode and cathode elements forms a cell, as shown in Figure 3. This cell can generate approximately 2 V of electromotive force. Because a larger plate area can yield greater current, several plates are connected in parallel in order to increase the current. To increase the voltage, two cells can be connected in series to yield 4 V, three cells connected in series to yield 6 V, four cells connected in series to yield 8 V, or six cells connected in series to yield 12 V. Ordinary car batteries are generally produced in this way. The cells shown in Figure 4 employ impact-resistant expanded polypropylene (EPP), which has been used to form six cells via injection molding. The anode plate and cathode plate will then be connected using soldered straps. The cathode strap from the other end of an anode output cell is soldered to the anode strap of the adjacent cell. Because the shorter the current path between two cells, the smaller the resistance between the cells, adjacent cells have a through connection to minimize resistance and ensure good discharge. Most car batteries employ this method. In the aforementioned six-cell battery, the cells and cell covers are bonded by thermal soldering, and each cell is sealed and separated from other cells. The cells are then filled with dilute sulfuric acid to complete the battery. When discharging, the PbO_2 of the anode reacts with the sulfuric acid to form lead sulfate ($PbSO_4$), and the lead of the cathode reacts with the sulfuric acid to form $PbSO_4$. The following chemical equations (1) to (3) occur during discharge [3, 4]:

$$\text{Cathode:}PbO_2+4H^{+}+SO_4^{2-}+2e^{-} \rightarrow PbSO_4+2H_2O \quad (1)$$

$$\text{Anode:}Pb+SO_4^{2-} \rightarrow PbSO_4+2e^{-} \quad (2)$$

$$\text{Battery:}Pb+Pbo_2+2H_2SO_4 \quad \rightarrow 2PbSO_4+2H_2O \tag{3}$$

The following chemical equation occurs when the battery charges.

$$2PbSO_4+2H_2O \rightarrow Pb+PbO_2+2H_2SO_4 \tag{4}$$

Reduction of $PbSO_4$ on the surface of the anodes to PbO_2 is the main chemical reaction occurring during charging, but secondary reactions involving loss of water and corrosion of lead also occur as follows.

$$PbSO_4+2H_2O \rightarrow PbO_2+H_2SO_4+2e^-+2H^+ \tag{5}$$

$$2H_2O \quad \rightarrow O_2+4H^++4e^- \tag{6}$$

H_2SO_4 is also reduced to lead on the surface of the cathode, at which time the following two reactions occur at the cathode.

$$PbSO_4+2H^++2e \rightarrow Pb+H_2SO_4 \tag{7}$$

$$2H^++2e^- \quad \rightarrow H^2 \tag{8}$$

After charging, the PbO_2 on the anode plate is restored, and the cathode becomes spongy as $PbSO_4$ on the surface absorbs electrons and is reduced to lead. In addition, the electrolysis of water leads to the release of oxygen at the anode and hydrogen at the cathode. Cell covers are equipped with cocks with small vent holes. Most ordinary batteries are of this type. Water will be lost due to evaporation after a battery has been in use for a period of time, and deionizer water must be added after the water level falls below the minimum level. Because adding water to batteries is troublesome for consumers, manufacturers developed batteries requiring no water addition. These batteries are often known as sealed lead-acid batteries (SLABS); calcium, instead of antimony, is alloyed with lead in this type of battery. Because the reduction of self-discharge causes the gassing point of hydrogen at the cathode to rise, the amount of hydrogen produced by electrolysis during charging is reduced in sealed batteries. The capacity of ordinary lead-acid batteries is expressed in Ampere-hours (Ah), which is the product of current (A) and discharge time (h). Because large capacity requires a large electrode plate area and large number of parallel electrode plates, a high-capacity battery will have a large volume. A 50Ah car battery should be able to produce a current of 5 A for 10 hours, which can be expressed as 0.1 C, or a current of 2.5 A for 20 hours, which can be expressed as 0.05 C. Starting a car engine requirements a transient current of approximately 100A-200A (depending on the type of car). Since the car engine is not running at this time, all power must be supplied by the battery. After float charging at a voltage of 14.4V, a car battery normally maintains a voltage of roughly 12.5 V. The transient starting voltage will fall to around 11 V (within three seconds), and may fall to 9-10 V if starting continues for five of six seconds. The voltage will drop more in winter than in summer. After the car starts, the generator will perform float charging of the battery at a voltage of 14.4 V. After the car is driven for a while, the charging current will gradually decrease.

Fig. 1 anode plates are arranged in an alternating arrangement

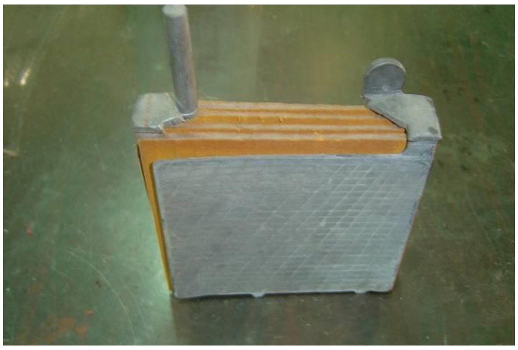

Fig. 3 the cells

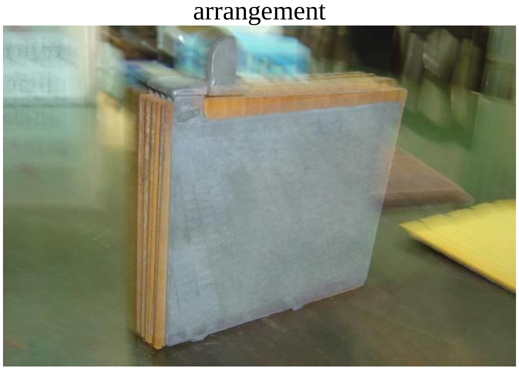

Fig. 2 cathode plates are arranged in an alternating arrangement

Fig. 4 storage battery

2. Design of an Automatic Testing Machine for Battery Soldering

The purpose of this research is to develop a device for inspecting a soldering point in a storage battery, which can provide inspection results for storage by an external processing device. This system shown as Figure 5 comprises a power supply unit and an inspecting unit. The power supply unit outputs a test power signal to be applied to the solder spot. The inspecting unit includes first and second inspecting terminals, and a control module. The first and second inspecting terminals are adapted to be connected electrically to the soldering point so as to detect response of the soldering point to application of the test power signal by the power supply unit. The control module determines if a detected response of the soldering point as detected through the first and second inspecting terminals falls within a predetermined range configured in the control module which generates an indication signal if the detected response falls outside the predetermined range, and generates an inspection result corresponding to the detected response.

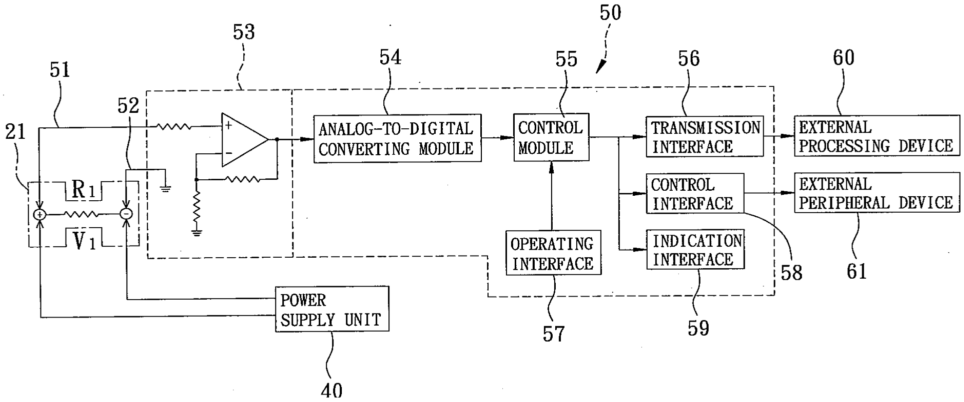

Fig. 5(a) a schematic sectional view of a conventional storage battery to be inspected by the device according to the present invention

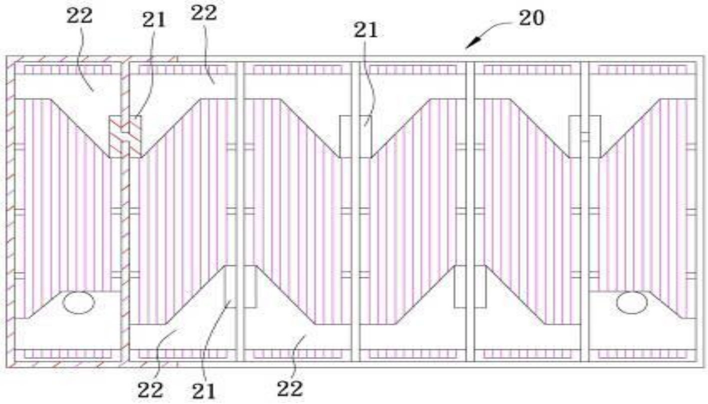

Fig. 5(b) a schematic view of the preferred embodiment of a device for inspecting a soldering spot in a storage battery

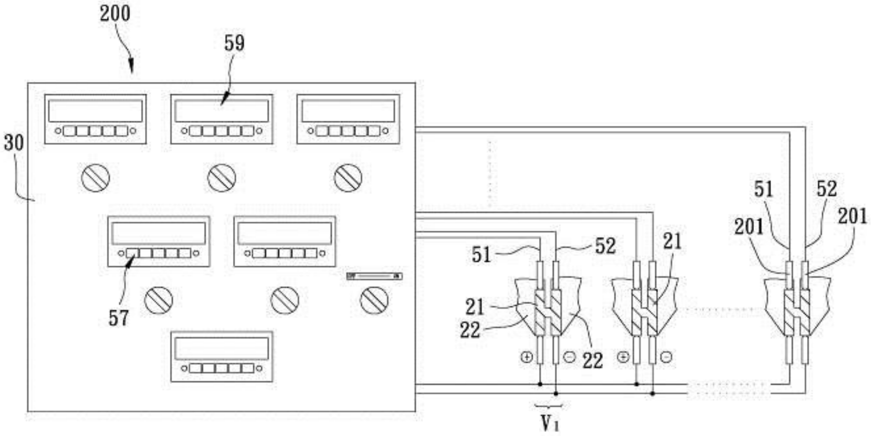

Fig. 5(c) a schematic block diagram of the preferred embodiment

The configuration of system is shown as follows.

200 ······ device for inspecting soldering spots in a storage battery

201	probes	20	Storage battery
21	soldering spots	22	lugs
30	housing	40	Power supply unit
50	Inspecting unit	51	First inspecting terminals
52	Second inspecting terminals		
53	input module	55	control module
54	an analog-to-digital converting module		
56	transmission interface	57	operating interface
58	control interface	59	indication interface
60	external processing device	R_1	resistance
61	external peripheral device	V_1	test source

The advantages of this testing machine include that inspection of the soldering points is conducted by the inspecting unit using electrical signals, the quality of the soldering points can be accurately determined. Furthermore, by outputting the inspection results through the transmission interface, the inspection results can be stored for the future evaluation of the quality if a batch of storage battery products.

3. Soldering Point Signal Processing Design

This soldering point testing machine's signal processing procedures and mechanisms are shown as follows:

A.Input signal: Because the signal from a soldering point is small and easily disturbed by the external environment (such as electric and magnetic fields), the signal must be first processed to determine the correct signal value.

B.Filter circuit: This circuit is laid out as shown in Figure 6, and has the following three main functions:

1)The filter circuit contains a low-pass filter comprising R1 and capacitor C1 to eliminate noise allow only the true signal to pass.

2)Overvoltage protection is provided by the two diodes D1 and D2. When an anomalous voltage occurs externally, the signal will remain clamped at a potential in the range of ±1 V, protecting IC elements.

3)The input impedance matching circuit relies on the high input impedance of operational amplifier U_1 (greater 3 MΩ) to reduce the effective load.

C.Amplifier circuit: This circuit serves relies on the operational amplifier and resistors R2 & R3 to amplify the small signal to a potential of 2Vdc,which is needed for subsequent processing by the analog-to-digital circuit. The amplification formula is shown as following.

$$\mathrm{Gain} = \frac{V_o}{V_i} = 1 + \frac{R2}{R3} \tag{9}$$

In order to ensure that the operational amplifier's Ib signals are the same, care must be taken to ensure that $R_1=R_2 \parallel R_3$. If the Ib signals are not the same, changes in the ambition temperature will affect the operational amplifier's output value, causing signal bias. Capacitor C2 in parallel with resistor R2 chiefly serves to eliminate signal instability due to noise from the operational amplifier at high amplifications.

D.Analog-to-digital circuit: Because the microprocessor can only read digital signals, and cannot read analog signals, this circuit is used to convert the analog signal to a digital signal. Attention must be paid to the resolution, sampling rate, and output connection when designing this circuit. The circuit is shown in Figure 7.

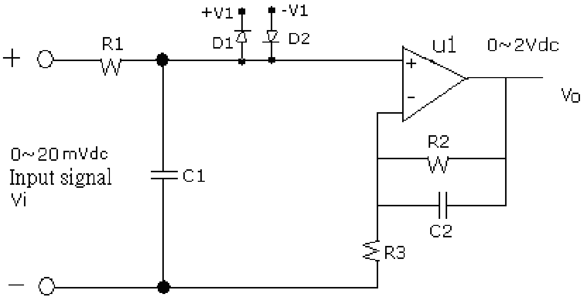

Fig. 6 filter circuit

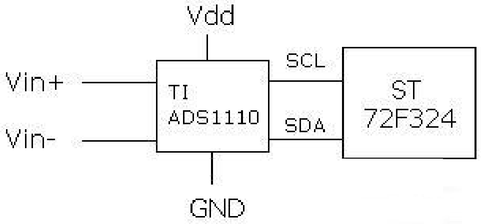

Figure 7: analog to digital circuits

The Ti Ads1110 IC is an analog-to-digital conversion circuit employing a differential model to encode a 0-2.048 Vdc analog signal as a 0-32767 digital signal. The resolution is 15 bots. and it employs a 12Cmethod. The circuit communicates with the microprocessor using SCL and SDA wires. The transmission rate is 15 times/sec.

E.Microprocessor: An ST 72F324 8-bit microprocessor is responsible for reading the digital signal from the previous analog-to-digital circuit. After processing and updating by the microprocessor's internal program, the signal is sent to a display showing the current value. Current values are also stored in memory, and are available for reading and use via a RS-485 communications cable. In addition, the microprocessor must also compare the relays' setting parameters with the current parameters; when the setting parameters are reached, a relay action signal output is sent to the corresponding relay. Finally, the microprocessor must also handle editing functions from the keyboard (such as relay action settings), and update the values stored in memory.

F.Display: The display shows the current value, relay output status, and computer online status. The display consists of a five-section display and LED circuit. The display's scanning connection with the microprocessor reduces the load on the microprocessor's I/O end. The microprocessor sends the number to be displayed to feet a-g, and also sends the potential to be displayed to the high-voltage position. This will cause the number to light up. For instance, if it is desired to display the number "2," the microprocessor will first connects feet c and f with high potential, and feet a, b, g, e, and d with low potential. It then sends high potential to D5 to display "2," This method is also used to send high potential to D4, D3, D2, and D1. Since the scanning rate is greater than the persistence of vision, a number with five places can be seen.

G.Relay output: Responsible for receiving signals from the microprocessor signal and activating the relay coils to change the state of relay contacts (such as by changing a normally open contact to a normally closed contact). Attention must be paid to relay contact capacity, and erroneous action due to insufficient contact capacity should be avoided.

H.RS-485computer connection: The RS-485employs the Modbns-Return communication mode, which involves a half duplex connection, for reading and writing. So-called half duplex refers to only being able to transmit or receive at one time, and not being able to simultaneously transmit and receive. Furthermore, the communications format must be the same as that of the server for a connection to be made. For instance, communications rate: such as 9600 bits/sec. or 19200 bits/sec.; parity detection: none, odd, the stop bit may be either 1 or 2.

I.Keyboard actions: The main keyboard functions are used in entering and editing customers' different setting points.

4. Automatic Testing System

A.The automatic testing system is shown in Figure 8. The testing steps are shown as follows.

1)Prepare the desired testing mold (tooling).

2)Turn switch "AUTO/MANUAL" to be "MANUAL".

3)Turn off the power of controller (SW1r).

4)Loose 2 screws of gate plates in front of mold(tooling) and then remove two gate plates, pull off plug then worker can remove mold.

5)Please put on the desired mold and let the gate plates hold mold then lock the screws; put on plug.

6)Turn off power of the weld checking controller, pull off plug on mold and loosen two fix handles on gate plate which is in front of the mold base, and remove mold. In reverse process, put on desired mold and plugs, and then turn on controller.

B.The adjust steps are shown as follows.

1)First, adjust the distance between both guide-rails to suit the battery width. The adjusting equipment is shown in Figure 9. Open the front fix handles(2 PCS) and switch the type selector to be the desired type, then push guide rail to end point tightly, finally to look fix handle (2 PCS). Secondly, open the rear fix handles (2 PCS), and adjust the inside width of guide rail larger than the battery width at 2 mm; after that lock the fix handle(2 PCS).

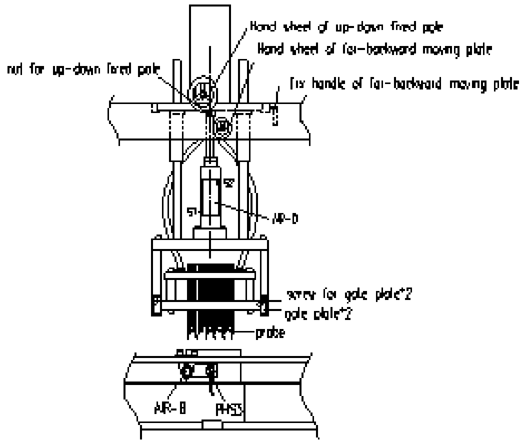

Fig. 8 automatic testing system

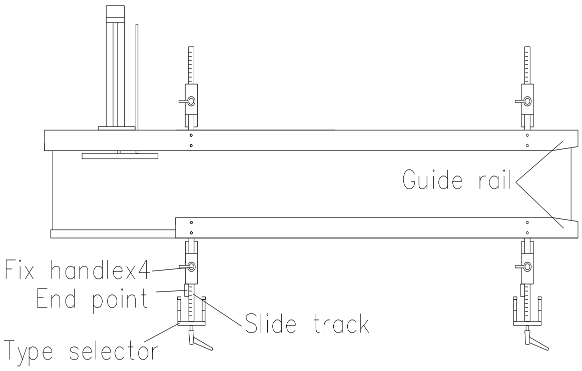

Fig. 9 adjusting equipment

2)Advance AIR B(by switch no.20) and loosen screw on AIR B, then accord to the testing position of battery to adjust AIR B position, and be sure that photo switch (PHS3) is ON once the front of battery is sensed shown as Figure 10.

3)Adjust the distance between photo sensor PHS2 and A to fit battery length; once the first battery is sensed by photo switch PHS2, the AIR advances to hold the second battery which is shown as Figure 11..

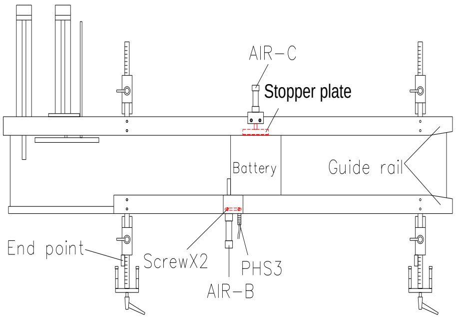

Fig. 10 battery in system

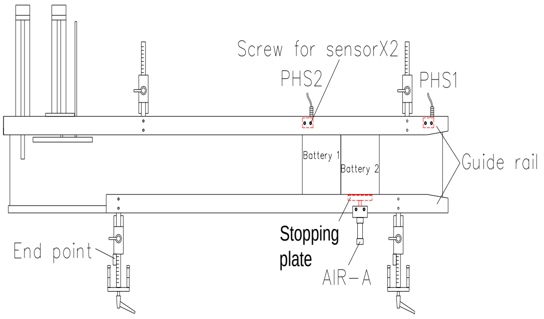

Fig. 11 Two batteries in system

4)Put one battery into testing area, turn on and adjust AIR B (by switch no.20) to hold the front of battery and then position AIR B. Lower AIR D (by switch no. 30) and loosen hand wheel of up-down fixed poles and handle of forward-backward moving plate, according to the battery height (let probes touch welded surface of elements group) to adjust them and be surd each probe touches plates, and then lock the hand wheel and handle.

5)Adjust the position of sensor PHS4, according to the length of battery and move it suitably (left or right) to let center of battery aim at center of AIR E to control NG battery position shown as Figure 12.

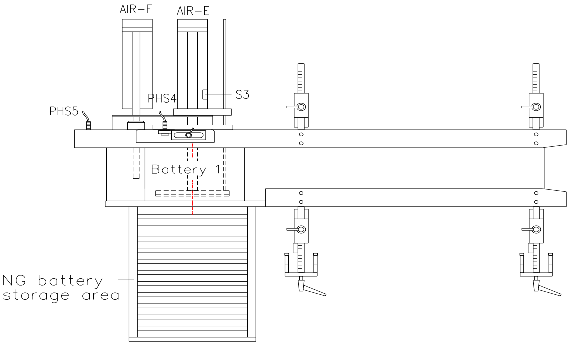

Fig. 12 NG battery position

5. Experiment Process and Result

When inspecting a storage battery, the test power signal (V1) is applied to the soldering points and the first and second inspecting terminal are coupled to the soldering points in pairs with the use of the probes. Since each soldering point has a small resistance (R1), the electric currents flowing through the soldering points as a result of application of the test signal (V1) can be converted by the analog-to-digital converting module into digital signals into resistance values corresponding to the soldering points. If the resistance value of one of the soldering points is determined to be a poor connection that needs to be re-soldered.

Since inspection of the soldering point is conducted by the inspection unit using electrical signals, the quality of the soldering points can be accurately determined. Furthermore, by outputting the inspection result through the transmission interface, the inspection result can be stored for future evaluation the quality of batch of storage battery products.

The testing machine can be installed in the auto-production line to inspect the soldering points of 12V-4AH battery. The resistance values of the soldering points are shown in Figure 13, which are 0.12, 0.07, 0.14, 0.08 and 0.13, respectively. The results show that each tab has different inside resistance. Each sampling of surface resistance isn't the same. But when the measuring value is over 0.2, it presents that the soldering point is fail. The Figure 14 shows resistance value: 0.15, 0.08, 0.13, 0.08and 0.25. Obviously, the last value is above general situation. After inspecting this battery, we find that the stander of solders level is only up to 60%. In order to have more examples, we test 36 batteries whose results are shown in Table 1. Certainly, different types of battery have different inside resistant and making the stander by examining ten batteries. Of course, the inspect machine we proposed is not perfect. The manufacture has to combine with practical experience for precise inspection. When the machine was used to inspect real battery soldering points, it was found that approximately 50 of every 1,000 batteries did not meet requirements. After individually inspecting these 50 batteries, correction was performed and the battery then retested if the electrode tab height was uneven. Afterwards, one defective product with poor soldering is on the right and left.

Fig. 13 The resistance value of the soldering points are shown in meter

Fig. 14 Another resistance value of the soldering points are shown in meter

Table 1 Test results for 36 batteries

BATT-SPEC 12V-14Ah		(0.20mv up badly) Sport checking record (using amp) 10. 2 A			
Term	Solder(1)	Solder (2)	Solder (3)	Solder (4)	Solder (5)
1	0.09 mv	0.10 mv	0.09 mv	0.09 mv	0.09 mv
2	0.08 mv	0.10 mv	0.09 mv	0.09 mv	0.09 mv
3	0.09 mv	0.10 mv	0.09 mv	0.10 mv	0.10 mv
4	0.12 mv	0.10 mv	0.09 mv	0.09 mv	0.10 mv
5	0.12 mv	0.11 mv	0.11 mv	0.11 mv	0.12 mv
6	0.10 mv	0.11 mv	0.11 mv	0.10 mv	0.10 mv
7	0.12 mv	0.07 mv	0.14 mv	0.08 mv	0.13 mv

8	0.11 mv	0.10 mv	0.11 mv	0.10 mv	0.10 mv
9	0.13 mv	0.12 mv	0.11 mv	0.12 mv	0.12 mv
10	0.11 mv	0.09 mv	0.10 mv	0.10 mv	0.09 mv
11	0.09 mv	0.11 mv	0.10 mv	0.10 mv	0.10 mv
12	0.15 mv	0.08 mv	0.13 mv	0.08 mv	0.25 mv
13	0.10 mv	0.10 mv	0.09 mv	0.09 mv	0.09 mv
14	0.12 mv	0.11 mv	0.11 mv	0.10 mv	0.11 mv
15	0.13 mv	0.11 mv	0.11 mv	0.11 mv	0.11 mv
16	0.11 mv	0.09 mv	0.10 mv	0.10 mv	0.09 mv
17	0.11 mv	0.11 mv	0.09 mv	0.09 mv	0.10 mv
18	0.09 mv	0.10 mv	0.09 mv	0.09 mv	0.09 mv
19	0.10 mv	0.09 mv	0.09 mv	0.10 mv	0.10 mv
20	0.09 mv	0.09 mv	0.09 mv	0.09 mv	0.09 mv
21	0.12 mv	0.10 mv	0.09 mv	0.09 mv	0.10 mv
22	0.12 mv	0.10 mv	0.09 mv	0.11 mv	0.10 mv
23	0.11 mv	0.11 mv	0.08 mv	0.09 mv	0.10 mv
24	0.09 mv	0.11 mv	0.10 mv	0.10 mv	0.11 mv
25	0.10 mv	0.09 mv	0.09 mv	0.09 mv	0.09 mv
26	0.10 mv	0.09 mv	0.08 mv	0.08 mv	0.09 mv
27	0.09 mv	0.08 mv	0.08 mv	0.08 mv	0.08 mv
28	0.09 mv	0.07 mv	0.08 mv	0.07 mv	0.09 mv
29	0.11 mv	0.09 mv	0.10 mv	0.09 mv	0.10 mv
30	0.11 mv	0.10 mv	0.11 mv	0.10 mv	0.09 mv
31	0.11 mv	0.10 mv	0.09 mv	0.10 mv	0.10 mv
32	0.12 mv	0.11 mv	0.09 mv	0.10 mv	0.09 mv
33	0.10 mv	0.10 mv	0.09 mv	0.10 mv	0.09 mv
34	0.11 mv	0.09 mv	0.10 mv	0.09 mv	0.10 mv
35	0.09 mv	0.09 mv	0.08 mv	0.08 mv	0.08 mv
36	0.10 mv	0.10 mv	0.09 mv	0.09 mv	0.10 mv

6. Conclusions

This study successfully developed a microprocessor controlled battery soldering point testing machine with automatic PLC operation. This machine can quickly identify batteries with poor soldering points. And will not affect battery quality. In addition, the soldering point testing machine can be used in conjunction with a computer to record battery soldering point characteristics for use in subsequent battery tracking.

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