Design of PLC-based Control System for 18650 Lithium-ion Battery Dismantling Machine

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Abstract. The dismantling process of 18650 lithium-ion battery aims to separate the shell from its contents that contain lithium. The dismantling process is carried out using pneumatic components that automated by using a programmable logic controller (PLC). This research was conducted through 5 stages of the process, namely: machine designing and manufacturing, pneumatic system designing, PLC control designing, assembly, and testing. The design of pneumatic systems and their control is carried out to get the easiest and most effective working system.

1. Introduction

The 18650 lithium-ion (li-ion) battery is the most common used battery type on the market today [1]. The battery has some of the most important building blocks, one of which is lithium. Lithium is an element that is scarce and difficult to obtain [2]. To overcome this, a recycling process is needed on the used li-on battery to recover the lithium [3]. The recycling process requires a device / machine to separate the battery shell from its contents containing lithium [4]. Based on this case, a research need to be conducted to examine and make a machine that can facilitate the disassembly of the 18650 lithium-ion battery.

2. Machine Designing and Manufacturing

18650 lithium-ion battery dismantling machine are designed using Autodesk Inventor Professional 2019, resulting final design which is shown on the Figure 1 and its components are shown on Table 1. Manufacturing process are using conventional tools and electric welding machine are used to weld the frame.

![Figure 1. Dismantling Machine Design](image)

Explanation :
1. Main Frame
2. Mini Grinder
3. Linear Actuator Cylinder
4. Cylinder Pneumatic Grinder
5. Hand Grinder
6. Linear Actuator Cylinder Mini Grinder
7. Solenoid Stopper
8. Cylinder Pneumatic Clamp
9. Panel Box
10. Cylinder Pneumatic Ejector
11. Assembly Vise
3. Pneumatic System Design

3.1. Pneumatic System Design Requirements
Machine could split the battery shell crossways and cut off both ends of the battery. It works in the following order: Clamp’s pneumatic locks the vise → Linear actuator moves forward to split the battery’s shell → Linear actuator stops on the first cutting position → Grinder’s pneumatic moves down → Grinder’s pneumatic moves up after it cuts the battery’s first end → Linear actuator moves forward → Linear actuator stops on the second cutting position → Grinder’s pneumatic moves down → Grinder’s pneumatic moves up after it cuts the battery’s second end → Clamp’s pneumatic opens the vise → Ejector pneumatic pushes the battery → Ejector pneumatic shortens → Linear actuator return to the initial position.

3.2. Pneumatic System Diagram
Pneumatic system diagram is shown in Figure 2. Clamp’s pneumatic is controlled with a 5/2 (S1 and S2) solenoid valve, linear actuator controlled with a 5/3 (S3 and S4) solenoid valve, grinder’s pneumatic controlled with a 5/2 (S5 & S6), ejector pneumatic controlled with a 5/2 (S7 and S8) solenoid valve, and linear actuator for mini grinder controlled with a 5/3 (S9 and S10) solenoid valve. Besides, speed control devices are installed in the clamp’s pneumatic S1 and S2 output, linear actuator in S3 output, grinder’s pneumatic in S5 and S6 output, and linear actuator for mini grinder in S9 and S10 output. For the pressure generation, an electric compressor with 8 bar of maximum pressure, 2 HP power, and debit of 195 liter/minutes are used to drive this machine. Before the air from the compressor enters into the system, the air pass through an air filter, regulator, and a safety valve.

![Figure 2. Pneumatic System Diagram](image)

4. PLC Control Design

4.1. PLC Input and Output
As the design of the pneumatic system that has been made, it is determined that the PLC used is the Omron CP1E-E30SDR-A. This PLC has 18 input, 12 output with 100-240V AC power supply and 24 VDC power output. Allocation of input and output address on the PLC can be seen on Table 1 and Table 2.

| ADDRESS | COMPONENT | INPUT SIGNAL          |
|---------|-----------|-----------------------|
| 0.00    | EMG       | Emergency pushbutton  |
### ADDRESS COMPONENT INPUT SIGNAL

| ADDRESS | COMPONENT | INPUT SIGNAL |
|---------|-----------|--------------|
| 0.01    | START     | Pushbutton Start |
| 0.02    | B         | Reed switch pneumatic clamp long |
| 0.03    | D         | Reed switch linear actuator position 2 |
| 0.04    | H         | Reed switch pneumatic grinder long |
| 0.05    | G         | Reed switch pneumatic grinder short |
| 0.06    | E         | Reed switch linear actuator position 3 (last) |
| 0.08    | A         | Reed switch pneumatic clamp short |
| 0.09    | J         | Reed switch pneumatic ejector long |
| 0.10    | I         | Reed switch pneumatic ejector short |
| 0.11    | C         | Reed switch linear actuator position 1 (start) |

### Table 2. Output Address

| ADDRESS | COMPONENT | OUTPUT SIGNAL |
|---------|-----------|---------------|
| 100.00  | S11       | Solenoid stopper shortens |
| 100.01  | S1        | Solenoid valve pneumatic clamp extending |
| 100.02  | S2        | Solenoid valve pneumatic clamp shortens |
| 100.03  | S3        | Solenoid valve linear actuator forward |
| 100.04  | S4        | Solenoid valve linear actuator backward |
| 100.05  | S5        | Solenoid valve pneumatic grinder extending |
| 100.06  | S6        | Solenoid valve pneumatic grinder shortens |
| 100.07  | S7        | Solenoid valve pneumatic grinder extending |
| 101.00  | S8        | Solenoid valve pneumatic ejector shortens |
| 101.01  | S12       | Solenoid relay grinder rotates |
| 101.03  | S13       | Solenoid relay mini grinder rotates |

### 4.2. System Software Design

A CX Programmer software was used to program the system control process, the flow chart was shown in Figure 3.
5. Assembly

Assembly process is performed on the pneumatic component and electrical component toward the dismantling machine’s frame. To ease the installation, a wiring diagram is made as seen in Figure 4.

6. Testing

A total of 10 lithium-ion model 18650 battery were tested on the dismantling machine shown in Figure 5 and recorded the time in each cycle in Table 4. While dismantled battery result is shown in Figure 6.
Table 3. Time Recording Results

| Test | Time (seconds) |
|------|----------------|
| 1    | 44.30          |
| 2    | 44.16          |
| 3    | 43.70          |
| 4    | 46.11          |
| 5    | 46.22          |
| 6    | 45.61          |
| 7    | 44.60          |
| 8    | 45.94          |
| 9    | 46.35          |
| 10   | 45.85          |

From Table 3, the average time for the 18650 lithium-ion battery dismantling process is 45.28 seconds. If the process is done manually it will require an average time of 80.54 seconds, so this dismantling machine could reduce the dismantling time to 35.26 seconds or 43.78%.

7. Summary

Battery dismantling machine able to be manufactured with a design that has been made and can be used for the process of dismantling a lithium-ion battery model 18650 by using the pneumatic control for the mechanism movement. The application of PLC to control the pneumatics ease the machine control, machine function flexibility, and simplify the electronic system. Based on test results, this machine could run as the PLC programmed and need a dismantling time with an average of 45.28 seconds.

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