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PERFORMANCE ANALYSIS OF POWER BANK FITTED WITH RECYCLED LAPTOP BATTERIES

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ABSTRACT

The result of observation at Science Laboratory of State Vocational High School 3 of Surakarta shows that the power capacity of power bank fitted with recycled laptop batteries was not tested. Power bank test was conducted by preparing used laptop batteries type 18650 from its packaging for a total of five cells, selecting batteries based on their physical appearance, cleaning the pole connections, testing the voltage, testing temperature when power charging from electric outlet to power bank, testing the power drain, testing the power capacity without load, charging in the case, testing the module when power charging from electric outlet to power bank, testing the power capacity level indicator, testing power charging from power bank to recharged device, installing the power bank analyzer, and recording voltage measurement results, electric current flowing, duration of time needed to charge, and power capacity left after charging. The electric load used was a 1.2 watt LED lamp. After that, the calculation of battery power capacity was conducted, in accordance with the technical specification listed in the power, then compared to the result of test of power capacity stored in recycled power bank. Based on the result of technical specification calculation, the power bank produced had a power capacity of 50.000 watt hours. Meanwhile, in the experiment with LED lamp electric load, the power bank had a power capacity of 44.6756 watt hours. The comparison of power capacity between the technical specification and the experiment shows that the recycled power bank had performance of 89.4%. Thus, recycled power bank met the requirement of feasibility to be learning media of physics project.

Keywords: work method; power bank; recycling; laptop batteries

INTRODUCTION

The word conservation is defined as a process of regular maintenance and protection to prevent damage, by way of preservation. Conservation can be interpreted as an act of doing protection and/or preservation, to preserve something from damage, destruction, loss, or else (Margareta et al. 2011). Dangerous and toxic material wastes can threaten the sustainability of environment. Conservation is a way to preserve environment, while still paying attention to possibly gained benefits at the certain time by keeping the existence of each component of the environment for future use. These wastes should be managed well so that they will not threaten the present and future generation (Suhadi, 2012). To decrease the environmental impact, lithium-ion portable batteries can be recycled with its volume expected to increase by a third from 2013 to 2017 (Boyden, S. & Doolan, 2016).

Lithium-ion batteries are the most common battery type used in portable electronic devices and their use is expected to double from 2013-2014 to 2019-2020. The recycling of lithium-ion batteries reduces energy consumption, reduces greenhouse gas emissions, and results in considerable natural resource savings when compared

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to landfill. However, it is unclear which recycling processes have the least impact on the environment. This paper will investigate the different processes that are currently used for recycling portable lithium-ion batteries, such as hydrometallurgy, pyrometallurgy, and combinations of processes. Surveys are carried out to understand the materials recovered from each process, and are obtained from several recycling companies around the world. A comparative life cycle assessment will be performed for two different recycling processes (hydrometallurgy and pyrometallurgy, by decreasing the mileage between collection and recycling.

One of the conservation efforts conducted is laptop battery recycle to power bank product. In this research, the most effective model was developed for system of interaction analysis between physical process and information stream, short-term and long-term effects to the environment from the portable battery waste (Blumberga et al., 2015). The developed model is important to be an input for policy makers on policy evaluation, collection, and steps.

The high number of gadget users is also followed by the increase of battery-dependent daily activities. A research places Indonesia on the top 5 gadget user in number, with 47 million of active users, or approximately 14% of overall number of gadget users in the world (Gifary, 2015). Other research shows that younger generation in Indonesia who have a high degree of education tend to use mobile internet, especially from smartphones (Puspitasari & Ishii, 2016). Meanwhile, personal computer is used for large-scale data management in information gathering in daily life. This finding also shows the importance of ICT education and the prospects of mobile internet segment in order to fill the digital gap with developing countries.

The growing number of gadget-dependent activities directly impacts to the growing number of consumption of battery energy. Battery is a part of gadget with the most rapid damage rate, yet it can still be recycled. The battery age can be estimated and investigated to find more optimal next generation batteries (Kalmykova et al., 2017).

A power bank is a device used to insert electrical energy to a rechargeable battery, without having to connect the device to electrical outlet. It can be used without having to connect it to an electrical device. It has electrical capacity so that when the energy contained in the power bank has been depleted, the power bank must be recharged by connecting it to an electrical outlet. It is mostly used to recharge gadget batteries. It is used by connecting the device connector cable to the portable battery charger. The connector cable connecting the device with the power bank is called USB connector, which is connected to the other end which is shaped like the customized device charger. There are some weaknesses in fast mode power bank battery charging, on the balance of charging time with the excessive raise of battery temperature (Zhang et al., 2017).

Portable battery device always develops from time to time, in its type of use, capacity, and energy density (Pistoia, 2009). The main component which constitutes a power bank is battery. There are also other components, namely: (1) lithium-ion rechargeable battery type 18650 which functions as energy storage which transforms chemical energy stored into electricity. It is like power bank module, which is an array of electronic device functioning to control electrical current flow when charging power from electric outlet to power bank and when charging power from power bank to recharged device (Schmalstieg et al., 2014); (2) LED indicator which functions to inform battery level at the time of power charging from electric outlet to power bank and power charging from power bank to recharged device; (3) Casing which functions as a storage place of power bank devices; (4) Port which functions as an in/out outlet at the time of entry and power charging from power bank to recharged device; and (5) connector, which is a cable connecting the charger to power bank or power bank to the recharged device. After assembly process, a set of recycled battery, module, battery charger level indicator, port, and connector cable will be used as a set of integrated instruments for project-based learning of Physics.

The level of motivation of students in Science learning is much better through battery project-based advance organizer learning model (Tasiwan et al., 2014). Project-based learning gives a limited illustration for big things which can form soft skills of conservation (Pavaloiu et al., 2015). There are five soft skills of conservation, namely love for environment, environmental consciousness, responsibility, objectivity, and honesty (Rosita & Marwoto, 2014). It is hoped that through cooperative model, the learning conducted can encourage students to learn more and work in groups related to certain courses. It is also expected that they will try to achieve the project goal synergically and will be much more ready for future work and technical competence. Lastly, it is expected that the students are able to use technology by correct and efficient means in product design, to understand new technologies, or to solve problems related to mechanism during product development and to build general discourse through various disciplines to comprehend the new technologies, to solve mechanism problems during product development and to establish a common discourse with other engineers during multidisciplinary work (Zadeh & Satır, 2015). This study focuses on the content of physics and related classes that belong to the curriculum of Industrial Product Design Department (IPDD. The main material taught was direct current (DC), with an emphasis to recycled laptop battery products. Power capacity is the amount of energy stored in a battery, indicacted by *miliAmpere hours* (mAh) (Ecker et al., 2014)

Based on the background of problems above, this research is focused on how to test the performance of power bank fitted with recycled laptop batteries if reviewed from power capacity as shown in specifications and power capacity proven through experimentation.

METHODS

This research used descriptive research type, by describing the performance of produced integrated instrument tools from recycled laptop batteries, which would be used for project-based learning in school laboratories (Lei et al., 2015; Hidayat, 2015). The battery used was a recycled used laptop battery type 18650, which had 5 battery cells variation (Love et al., 2014).

The research was conducted in several stages: disassembling the casing of the used laptop battery, analyzing the physical feasibility, cleaning the welding point of positive and negative poles of the battery to remove any toxic materials (Fu et al., 2015), measuring the voltage, charging and draining the battery content (Keil & Jossen, 2016), analyzing temperature when power charging from electric outlet to power bank (Waldmann & Wohlfahrt-Mehrens, 2017) "ISSN": "00134686", "abstract": "During charging at low temperatures, metallic Lithium can be deposited on the surface of graphite anodes of Li-ion cells. This Li plating does not only lead to fast capacity fade, it can also impair the safety behavior. The present study observes the effect of rest periods between Li plating and subsequent accelerated rate calorimetry (ARC, installing the battery in integrated instrument tools, analyzing power capacity level indicator lamp (Kornbluth & Erickson, 2012) health, and environmental costs of kerosene, candles, and other fuel-based lighting are well-documented. As a result of efforts by the World Bank and other organizations, numerous lighting products incorporating solar photovoltaic and light-emitting diodes (LEDs), trying the circuit by adding electric load, analyzing voltage when power charging from power bank to recharged device, analyzing transferred power capacity, and analyzing the time needed to charge device using power bank. The nature of conservation in learning is aimed to accustom students to behave in an environmentally friendly behavior, since the natures of conservation are to care, protect, and repair the environment (Machin, 2013).

Instrument testing was conducted to 6 integrated instrument tools of power bank fitted with recycled used laptop batteries, each consisted of 5 cells of type 18650 battery. The experiment was conducted alternately, in February – March 2017. The data were collected through observation during power bank experiment by project instrument. Instrument data collection was conducted to represent overall integrated instrument tools of power bank. They were then analyzed by descriptive method, both quantitative and qualitative consisting of data reduction and process of determining conclusion.

RESULTS AND DISCUSSION

The research was conducted through stages as follows: (1) disassembling the casing of the used laptop battery; (2) analyzing the physical feasibility; (3) cleaning the welding point of positive and negative poles of the battery to remove any toxic materials; (4) measuring the voltage; (5) charging and draining the battery content; (6) analyzing temperature when charging power from electric outlet to power bank; (7) installing the battery in integrated instrument tools; (8) analyzing power capacity level indicator lamp; (9) trying the circuit by adding electric load; (10) analyzing voltage when power charged from power bank to recharged device; (11) analyzing transferred power capacity; and (12) analyzing the time needed to charge device using power bank.

The disassembling process of laptop rechargeable battery type 18650 resulted in product as shown in Figure 1. Based on the technical data, type 18650 batteries have some specifications, namely: 18 mm diameter, 65 mm height, 4.2 volt voltage, 2000 mAh power capacity.

Figure 1. Type 18650 Batteries Fitted with Recycled Laptop Batteries

There were some physical indicators used to indicate that the batteries still worked normally, namely: 1) not excreting fluids or gases; 2) not having any bulge; and 3) not corroding. The performanceof rechargeable batteries is the most important thing in power bank circuit.

The desired power bank module is shown in Figure 2. A power bank module consisted of some components: 1) 5 compartment batteries channel; 2) Micro USB charging socket with specification of 5V ± 5% ≡1A; 3) electrical outlet-to-power bank charging protection circuit; 4) 4 LED power capacity level indicators; 5) power bank-to-recharged device charging protection unit; 6) female USB port with specification of 5V ± 5% ≡2,1A; 7) power indicator lamp; 7) on/off switch.

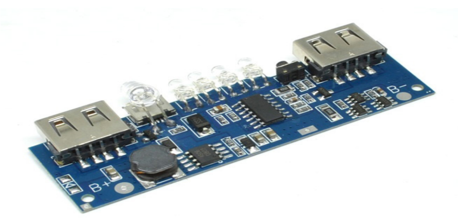

Figure 2. Power Bank Module

The power bank casing used in this research is shown in Figure 3. It had some features as follows: 1) It was made of PP Plastic Compound; 2) it had USB and micro USB slots; 3) it enabled the users to change the battery by themselves. The arrangement for batteries is in parallel circuit.

Figure 3. Power Bank Casing

The electrical load used to test the produced power bank was a portable LED lamp consuming 1.2 watt on 5 volt voltage, connected through USB port, as shown in Figure 4.

Figure 4. 5 volt, 1.2 watt USB Portable LED Lamp

The experiment was conducted by following scheme as shown in Figure 5. First, 5 type 18650 batteries were installed in parallel circuit, and then they were connected to the power bank module. After that, analyzer was installed, and finally, an electrical load of portable LED lamp was connected.

Based on technical data, type 18650 batteries had 4.2 volt output voltage and 2000 mAh power capacity. If 5 parallelly-arranged battery cells were used in an integrated instrument tools, the ideal battery capacity accumulation produced in accordance with technical specification was 5 x 2000 mAh = 10000 mAh.

The calculation of power bank capacity according to specifications prescribed was 10000 mAh, meaning that the battery could provide electrical current of 2.1 A for 10000/2100 = 4.762 hours, as shown in Figure 6. Based on the energy equation of E = P x t = V x I x t. It could be calculated that 5 volt x 2.1 ampere x 4762 hours = 50.0 watt hours. Therefore, the energy storage capacity of power bank tested was 50.0 watt hours.

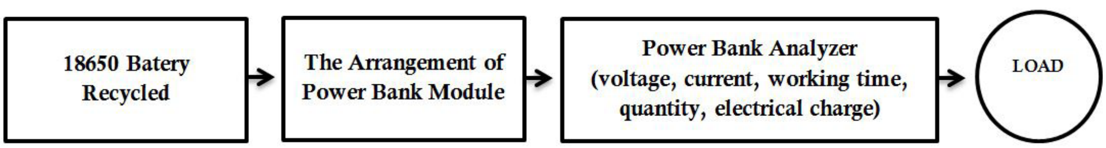

Figure 5. Scheme of Performance Analysis of Power Bank Fitted with Recycled Laptop Batteries

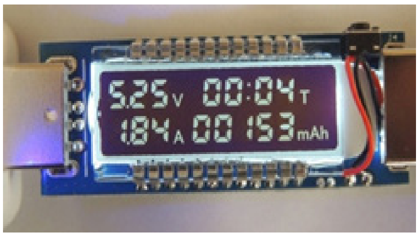

Figure 6. Power Bank Battery Analyzer (Voltage, Electrical Current, Working Time, Battery Power Capacity)

Visually, the result of power bank capacity test with electrical load is shown in Figure 7. The power bank capacity was drastically reduced when connected to electrical load, at the time when the voltage reached 3.7 volt. After that, the voltage was stable, at the range of 3.0 volt without experiencing any reduction, even though the load was still connected. However, in this situation, the current rate to the electrical load stopped, in a condition as same as when the switch opens. In a normal battery, the minimal lowest voltage is 3.0 volt. If the battery voltage is under 3 volt, it indicates that the battery may be broken.

From the calculation according to data obtained from measurement, it was found that the electrical current was 0.21 ampere, the voltage was 5.22 volt, and the time estimation was 40.755 hours. Thus, the energy capacity = $P \times t$ = $V \times I \times t$ = 5.22 volt x 0.21 ampere x 40.755 hours = 44.6756 watt hours. Based on the calculations, the comparison between the energy capacity based on specification and the energy capacity based on measurement was 89%.

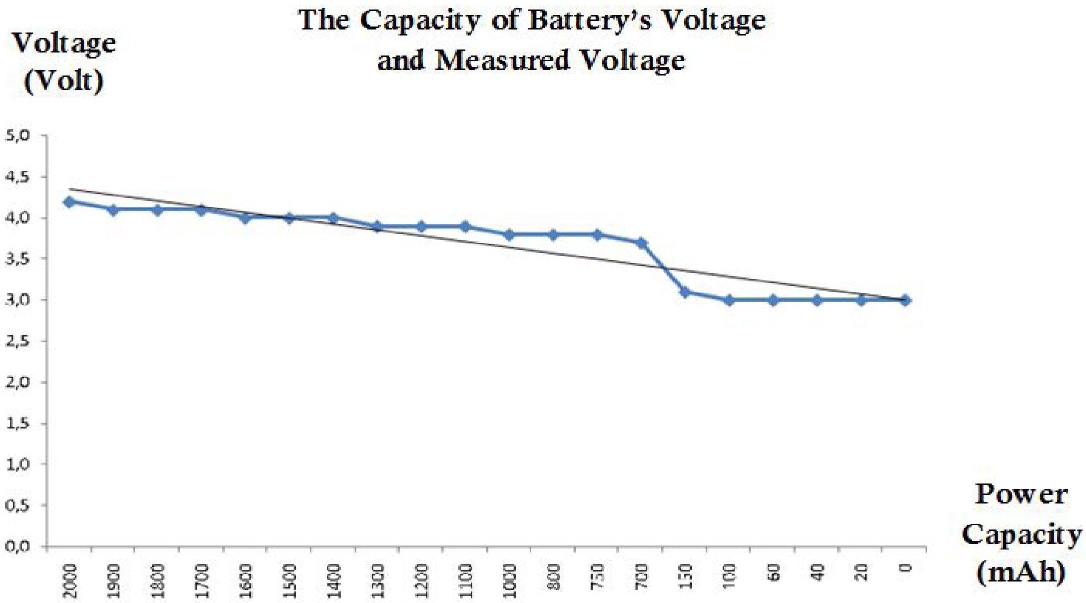

Figure 7. Measurement and Analysis of Battery Power Capacity when Connected to Electrical Load

Since the load requirements of power bank in this experiment was a 5 volt LED lamp, then the power bank should convert the battery voltage from 4.2 volt to 5 volt, so that the mAh value of power bank also changed in accordance with the comparison value of battery voltage with output voltage formed. In this case, the constants of multiplying factor to the mAh of power bank appeared which was resulted from calculations of 4.2 volt/5 volt = 0.84. It should be noted that each power bank had its certain efficiency level, meaning that not all mAh could be fully stored 100%. It was caused by the material and electronical limit of power bank, which resulted in the loss of charge capacity, or in other words, unstored charge capacity, assuming that the power bank was still capable in storing power, with 90% efficiency level. Based on the data of constants of multiplying factor and efficiency level of power bank, then it can be assumed that a power bank with 10000 mAh specification had the actual mAh value of 0.84 x 10000 x 90% = 7560 mAh.

Table 1 shows that the indicator of capacity level of battery based on measurement result indicated the accuracy of LED view. In addition to showing the change in total LED lit, the indicator also marked power charging from electric outlet to power bank and power charging from power bank to recharged device by blinking with the same frequency of blinking in each lamp.

Table 1. Indicator of Capacity Level of Power Bank Battery

LED Color	Battery Level (%)	Voltage Range (Volt)	Info
Dull Red	0 - 25	3.00 – 3.59	Low
Bright Red	25 - 50	3.60 – 3.89	Middle
Yellow	50 - 75	3.90 – 4.04	High
Green	75 - 100	4.05 – 4.20	Full

Overall, the performance of each part of power bank was in accordance with the plan. This shows that integrated instrument tools of power bank by using recycled laptop battery product could be used as learning media for project-based physics course. At the time of charging power from electrical outlet to power bank, the battery did not reach 60^{o} C in normal charging time. At the time of charging power from power bank to recharged device, the battery delivered the current steadily. The parallel circuit of 5 type 18650 battery cells with different capacities could have the performance f 89.4% after experiment, compared to technical specification work method.

CONCLUSION

It was discovered from this research that the performanceof power bank using recycled laptop battery which would be used as a project learning media at Vocational High School was 89.4%, compared to the technical specification, based on the data obtained. The integrated instrument tools of power bank using recycled laptop battery is feasible to be used as a learning media for project-based course, especially at Vocational High School with ICT area of expertise. In the future, it is hoped that the development of integrated instrument tools can be directed to using alternative energy resources, such as adding solar panel modules.

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