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Influence of Battery Charger Types on Batteries' Electrolyte Temperature during Charging in Eldoret Town, Kenya

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Abstract - The study involved experimental design in which 10 battery charging stations were studied, with respect to each charger type. Temperature was recorded on electrolyte during charging on regular time intervals. The mean temperature of electrolyte in batteries charged by both chargers were significant at α=0.05 (t = 5.273, df = 1, p = 0.0000). Charging of different types of batteries by an industrial charger was not significant (t = 0.443, df = 4, p = 0.778), likewise the batteries charged by the Jua Kali charger was also not significant (t=0.277, df=4, p=0.983). However, individual batteries charged with industrial chargers produced higher temperatures ($p<0.05$). Capacity test on the two sets of experiments showed that the batteries charged by Jua Kali chargers produced 50% of the charge when compared with batteries charged by industrial chargers. New design consideration must be added to the Jua Kali charger for improved charging.

***Keywords* - Charge, Charger type, Temperature, Electrolyte.**

1. Introduction

For three centuries now, people have depended on electrical energy, a phenomenon without which our technological evolution would not have been possible. In Kenya between 2%-5% of rural and peri-urban households have access to electricity derived from rechargeable car batteries [1]. Charging of batteries has for decades evolved, as there is always a growing need to give the end user more feedback on the factors affecting state of charge of a given battery [2]. The two main states of charge known to people are on overcharged batteries always believed to be gassing and undercharged batteries, always supplying power to loads attached to them for a very short time. Several types of rechargeable lead acid batteries including those of; flood, valve regulated, thin film, sealed lead acid and deep cycle batteries exist in the market today. These batteries require regular charging from different sources which include solar energy, wind energy and hydroelectric power as they lose their chemical energy due to surface discharge and through loads connected to them. Such energy conversion will only occur if there exist a suitable and efficient energy converter.

The Jua kali electrical artisans have used local scrap metal materials especially in the design and construction of the core of some transformers, which are used in manufacturing Jua kali lead acid battery chargers. This has been an important attempt to conquer new sources of raw materials by recycling used metal sheets. The technological evolution used in product construction and design has been in form of replication by applying use of reverse engineering [3][4].

Reverse engineering being a technological reinvention process entails measurements, analysis, and tests meant to reconstruct the mirror image of an object. Such process requires the designer to have an understanding of the functionality of the original part and the skills to replicate its entire characteristic details as is done by manufacturers all over the world. The new analytical technologies, such as three-dimensional (3D) printing and laser scanning, have made reverse engineering easier, but there is still much more to be learned [5].

The battery chargers produced by the Jua kali electrical artisans lack essential information about their performance and may be seen to compromise quality. The missing information includes operational manuals, nameplates, durability and guarantee of replaceable parts. This suggests that buying the Jua kali charger today is a game of trial and error as far its operation is concerned. Despite missing information, people have rushed into buying these items since they are affordable and their effects on the battery during charging are never known to public or even to the jua kali manufacturers, for business persons are after profits while customers are after services, which they seem to trust. Design and construction of energy efficient battery chargers is not only a cost effective way of getting energy but a must be done strategy as we move towards societies that embraces green energy.

2. Objective of the Study

The objective of the study was to determine the influence of charger type on electrolyte temperature variation during charging.

3. Research Methodology

3.1 Experimental Design

The research study conducted was quantitative in nature. It constituted two experimental units on a purposive sample of two charger types, i.e. Jua kali battery chargers manufactured by the informal sector and the industrial chargers manufactured by the formal industries. The two charger types acted as treatments to the batteries that were being charged, with the industrial charger set being used as control. A total of 20 battery charging stations were studied of which it was divided equally between the two charger types. In each battery charging station 5 different types of vented lead acid lead acid batteries were charged. This meant the experiments constituted a five level factor on each charger type. Time was recorded on one hour time interval.

In determining the capacity of charged batteries, accumulators were discharged at the same rate using a constant resistive load draining, 25A until when the open circuit voltage was 10.50V or 1.75V/cell [6][7]. The values of voltage, temperature and time during discharge were recorded on 10 minute time interval. The types of accumulators used were the chloride exide, KV, 3K, AP, and Dynagrid. Those batteries charged by industrial chargers were coded as Chloride Exide1, KV1, 3K1, AP1, and Dynagrid1, while those charged by the jua kali chargers were coded as Chloride Exide2, KV2, 3K2, AP2, and Dynagrid2. The batteries used were expected not to be older than 3 months since the date of purchase when new and were all rated at the same capacity of 12volt, 32 AH. KV1 and KV2 were brand new batteries, hence acted as controls on batteries charged by the two charger types.

The student t-test and one way ANOVA was used to analyze if there existed influence in variables between the industrial charger and the Jua kali charger on the batteries charged, with level of significance taken to be at $\alpha=0.05$. Univeriate data analysis allowed for trends to be clearly understood in relation to the test of significance obtained.

4. Results and Discussion

4.1 Charging

The objective of the study was set to determine the influence of charger type on the temperature variations during charging. The result of electrolytic temperature variation of batteries is shown in Figure 1. There were significant differences ($t = 5.273$, $df = 1$, $P = 0.0000$) in the temperature ranges between the electrolytes of batteries charged using industrial charger and Jua Kali charger. Batteries charged with industrial chargers had higher mean temperature than those charged with the Jua Kali chargers.

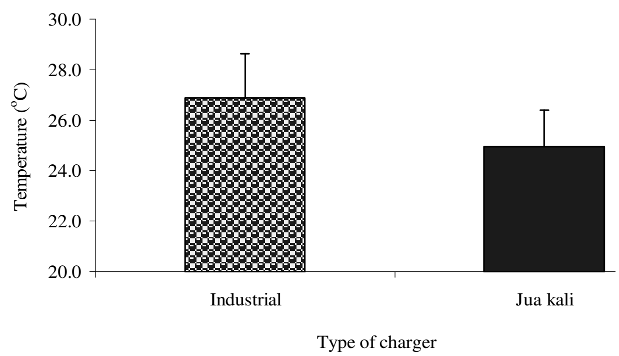

Fig. 1 Mean temperature (^{O}C) of electrolytes in the batteries charged by the two battery charger types

This was attributed to a reduction in internal resistance in batteries charged by the industrial chargers as compared to batteries charged by the Jua Kali chargers that had high internal resistance. This is consistent with earlier work done by [8] where it is argued that internal resistance of a galvanic cell is temperature dependent, decreasing as the temperature rises due to the increase in electron mobility. Thus the cell may be very inefficient at low temperatures but the efficiency improves at higher temperatures due to the lower internal impedance. However, [9] pointed out that the Joule heating effect of the I^2R losses due to internal resistance of the cell will cause the temperature of the cell to rise. The voltage drop and the I^2R losses may not be significant for small batteries but is highly significant when it comes to batteries with 100cells and capacities of 200 AH batteries. [10] further points out that the energy stored within a battery cell is the result of an electrochemical reaction that is directly proportional to temperature change of the electrolyte and is determined by input voltage and current to the battery.

Results showing the differences in electrolytic temperatures of specific types of batteries charged with industrial chargers as compared to those charged with Jua kali chargers are as shown in Table 1. There were no significant differences in the temperature of electrolytes among the individual battery types charged by industrial chargers ($F = 0.443$, $df = 4$, $P = 0.778$). Likewise, individual electrolyte temperature ranges for batteries charged with Jua kali chargers did not exhibit any significant differences, ($F = 0.277$, $df = 4$, $P = 0.983$). However, the individual batteries charged with industrial chargers were all consistently producing higher temperatures ($P < 0.05$) than batteries charged with Jua kali chargers.

Table 1: Mean temperature (^{O}C) of electrolytes during the battery charging

Battery type	Industrial	Jua Kali
Chloride Exide	27.1 ± 0.7^{b}	24.5 ± 0.4^{a}
KV	27.2 ± 0.7^{b}	24.9 ± 0.4^{a}
3K	26.8 ± 0.6^{b}	25.0 ± 0.7^{a}
AP	27.2 ± 0.7^{b}	25.3 ± 0.6^{a}
Dynagrid	26.2 ± 0.6^{b}	25.0 ± 0.5^{a}

Mean values are significantly different at $\alpha = 0.05$. The superscript "a" and "b" denotes the standard errors resulting from deviations about the mean.

The results in table 1 shows mean temperature of electrolyte of batteries of same capacities that were charged and is supported by research done by [11], in which it is noted that different battery chargers have different charging abilities, hence a clear variation in batteries temperature reached during charging.

Trends in temperature changes in the batteries during charging using industrial chargers and Jua kali chargers are indicated in Figure 2. From the graph, temperature of industrially charged batteries consistently increased for 6 hours to maximum temperature above which any further charging resulted to reduction of battery temperature. On the other hand, continuous charging of the batteries with the Jua kali chargers resulted in increased battery temperature even after 6 hours of charging.

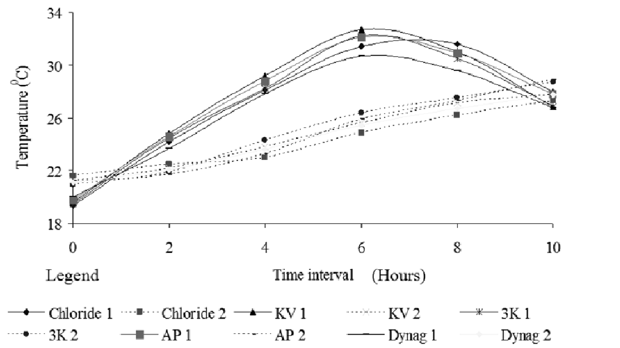

Fig. 2 Trends in temperature (^{O}C) changes during battery charging after charging with the two types of chargers

The results in figure.2 shows that temperature of batteries charged by industrial charged batteries consistently increased for 6 hours followed by a reduction in the next 4 hours to the 10th hour of battery charging, this relates to earlier studies done [12] where it is argued that the essence of good charging is to be able to detect when the reconstitution of the active chemicals is complete and to stop the charging process before any damage is done while at all times maintaining the cell temperature within its safe limits. On the other hand, continuous charging of the batteries with Jua Kali chargers resulted to temperature increase even after 10 hours of charging. This showed that the Jua Kali charger does not regulate electrolyte temperature in the battery by minimizing temperature as the battery nears full charge.

Hence relating with studies conducted by [13][14] where it is argued that controlled overcharging is essential in getting optimum charge. Thus it is emphasized that there is need to maintain the rate of chemical reaction within design parameters so as to alter the charge voltage at a rate proportional to the change in temperature, that is decreasing the charge voltage with an increase in temperature above 20°C and increasing the charge voltage with a decrease in temperature below 20°C [10]. The typical change in charge voltage should be 3 mV / °C. [15] further argues that between 80%-100% capacity, the impedance behavior becomes non-linear, and the impedance increases as the battery approaches fully charge increasing the temperature, and thus temperature has to be regulated by reducing charging voltage and current

4.2 Discharge

The result of electrolytic temperature of batteries during discharge is shown in Figure 3. There were significant differences ($t = 6.219$, $df = 1$, $P = 0.0001$) in the temperature ranges between the electrolytes of batteries discharged after charging using industrial charger and Jua

Kali charger. Batteries discharged after charging with industrial chargers had higher mean temperature than those charged with the Jua Kali chargers.

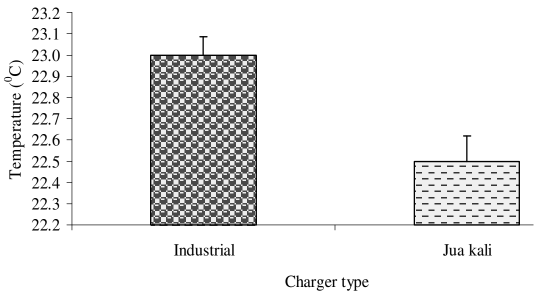

Fig.3: Mean temperature (^{O}C) of electrolytes during battery discharge after charging with the two types of chargers

Results showing the electrolytic temperatures of specific types of batteries during discharging after initial charging with industrial chargers and Jua kali chargers are shown in Table 4.2. There were no significant differences in the temperature of electrolytes among the individual battery types charged by industrial chargers ($F = 1.449$, $df = 4$, $P = 0.078$). Likewise, individual temperature ranges for discharged batteries after charging with Jua kali chargers did not exhibit any significant differences ($F = 0.277$, $df = 4$, $P = 0.983$). However, the individual batteries discharged after charging with industrial chargers all had higher electrolytic temperatures ($P < 0.05$) than batteries discharged after charging with Jua Kali chargers.

Table 4.2: Mean temperature (^{O}C) of the electrolyte during battery discharge

Battery type	Industrial	Jua kali
Chloride Exide	23.31 ± 0.21^{b}	23.05 ± 0.27^{a}
KV	23.80 ± 0.24^{b}	22.60 ± 0.27^{a}
3K	22.69 ± 0.16^{b}	22.26 ± 0.31^{a}
AP	22.58 ± 0.16^{b}	22.46 ± 0.25^{a}
Dynagrid	22.72 ± 0.17^{b}	22.13 ± 0.16^{a}

Mean values are significantly different at $\alpha = 0.05$. The superscript "a" and "b" denotes the standard errors resulting from deviations about the mean.

Trends in temperature changes in the batteries during discharging after charging using industrial chargers and Jua Kali chargers are indicated in Figure 4. From the graph, temperature of industrially charged and Jua kali charged batteries consistently increased from the onset of discharging without any discernable pattern variation between the batteries charged by the two charger types. However batteries charged by the industrial battery and Jua Kali chargers took about 70 and 35 minutes respectively to discharge to terminal voltage of 10.5 V.

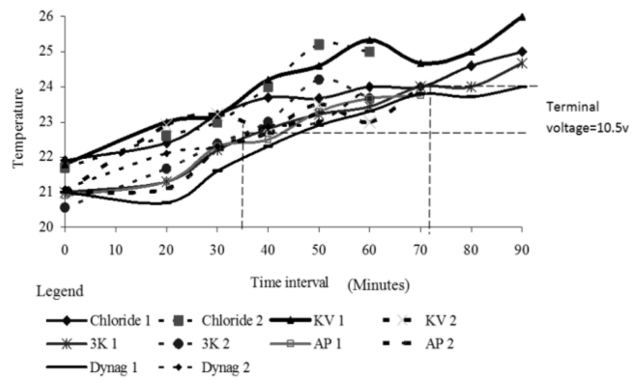

Fig.4: Trends in electrolyte temperature (^{O}C) changes during discharge of batteries charged by the two types of chargers

The electrolyte temperatures among individual battery types charged by the industrial charger were not significantly different during discharge. Likewise, individual temperature ranges for discharged batteries after charging with Jua Kali chargers did not exhibit any significant differences. However, the individual batteries discharged with industrial chargers all had higher mean electrolytic temperatures than batteries discharged after charging with Jua Kali chargers. This resulted due to the longer time taken by the industrial charged batteries to fully discharge as compared to the Jua Kali charged batteries that took shorter time, hence on average the industrial charged batteries were seen to have stored more energy than the Jua Kali charged accumulators due to prolonged chemical reaction.

5. Conclusion

Poor charging practice is responsible for shortening the life of batteries more than any other cause. The influence of charger type on the temperature showed that the batteries charged by Jua Kali chargers had lower values as compared to the batteries charged by the industrial chargers. The charging mechanism of the Jua Kali chargers thus depicted the undercharging of batteries, which poses danger to the batteries being charged. The effects of such chargers on batteries include sulfation of plates, waste of time and money in the event that batteries are damaged beyond control. The Jua Kali charged batteries were approximated to supply electrical energy half way those of batteries charged by the industrial chargers as the disconnect voltage was expected to be 10.5 volts. This thus invokes the need to look into ways of improving the design of the Jua Kali manufactured battery charger to match those of industrial type.

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