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AG/ZN BATTERIES IN HIBRID AIRCRAFT SYSTEMS

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Abstract
Nowadays people develops and uses electrical vehicles. Electrical cars can be seen everywhere in the roads. Making electrical aircraft is a more complex problem. In this paper we would like to introduce the reader into the world of electrical aircraft systems. There are some basic definitions about the topic. The lithium based batteries are compared with the silver-zinc batteries. Because of safety issues Ag/Zn batteries are preferred.

1 Introduction

Nowadays, creating electrical transport vehicles is an actual topic of the science and the industry. There are a lot of active development areas about this technology. There are two major concepts in the aircraft industry. The More Electric Aircrafts (MEA) and the All Electric Aircrafts (AEA) [21]. Using more energy storing capabilities can improve the total flight length and makes shorter the flight time on the same distance. There are a lot of chemical systems used by battery developers to reach the high requirements of flying machines shown on Figure 1.

Figure 1. Progress in these areas requires advances in safe, very high energy batteries [3]

Some applications like torpedoes [6] are allow to using primary batteries, but especially in the most of aircraft applications secondary batteries are needed, which batteries are rechargeable [24].

Batteries are built up from connections of electrical cells, it can be seen on figure 2. That's why some people call them battery packs. [10]

Figure 2. Mars Pathfinder. Silver-Zinc Battery. (Photo courtesy of Jet Propulsion Lab.) [9]

Battery can be electrical or thermal overloaded. Explosion can be happened in a thermal runaway of a battery, as it can be seen on figure 3.

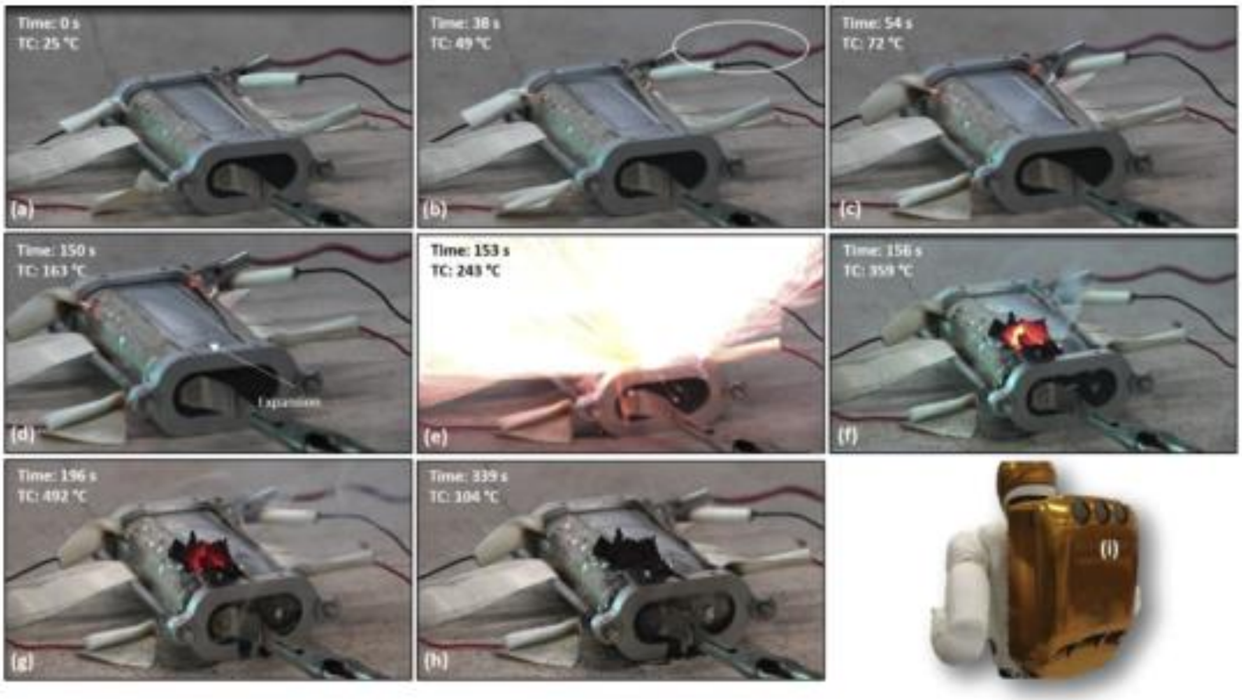

Figure 3. Images of a Li-ion cell throughout an open atmosphere patch heater induced thermal runaway event: (a) prior to heater instrumentation, (b) when smoke is first observed, (c) when smoke generation rates significantly increase, (d) moments before runaway occurs, (e) the instant that runaway occurs, (f) still heating from decomposition reactions following explosion, (g) when maximum temperature of 492 ^{0}C is achieved, (h) following a portion of the cool down period, (i) is an image of the R2 battery backpack that will contain 300 of the cells. [25]

Special safety instructions have made to avoid catastrophic explosions. All used batteries should fulfill the safety requirements. [19] In this paper we will demonstrate why Ag/Zn batteries are preferred in aircraft industry than Lithium based ones.

The popular and dangerous lithium battery technology is shown in the second section. The third section contains a short description about the silver-zinc battery technology. The fourth section of this paper shows the applications of silver-zinc batteries. The fifth section comparison of the presented battery technologies.

2 Lithium-ion battery

Very popular battery rechargeable battery type. Nowadays it is the most researched battery type. It has good electrical parameters, but it is strongly flammable. Batteries must be designed to mitigate against a catastrophic fault in one cell, like: thermal runaway conditions, short circuits, or open circuits. Lithium-ion batteries with solid electrolytes can improve inherent safety. Higher temperature limit is allowed by the solid electrolytes because they are non-flammable [3].

An airplane has to make emergency landing in Japan, Jan, 2013 because of Lithium-ion battery got damaged, see on Figure 4.

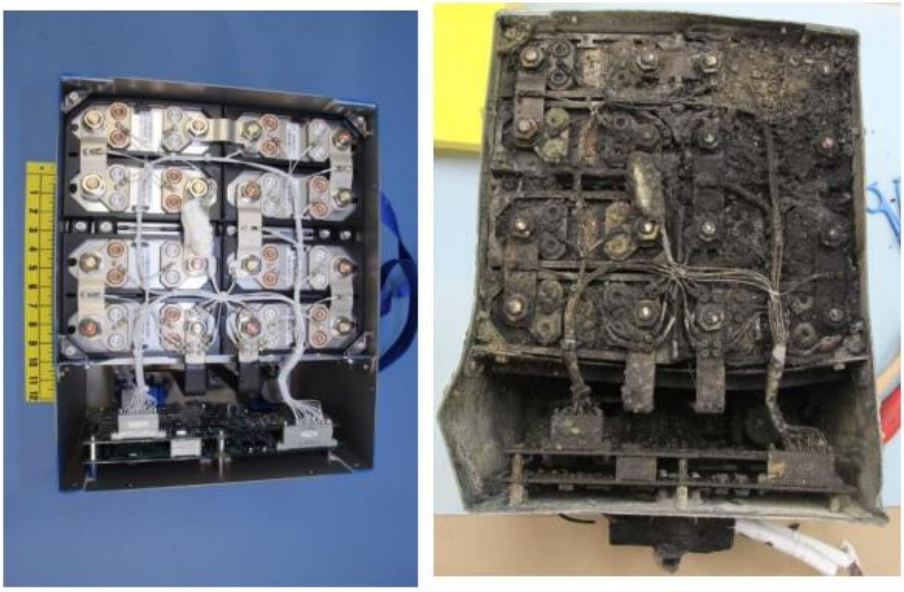

Figure 4. Japan Airlines 787 Battery – Exemplar Battery and Aftermath of Jan 2013 Fire Courtesy Emergency Landing was needed [3]

It is not allowed to take them to an airplane journey [1, 2]. Restraining table can be seen on Figure 5.

Figure 5. Danger table against Lithium containing batteries [1] lithium_batteries.pdf

3 Silver-zinc battery

Silver-zinc battery technology use Silver for cathode and Zinc for anode [8]. The set-up of one cell can be seen on Figure 6.

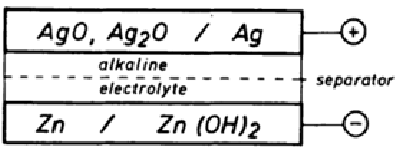

Figure 6. Set-up of a silver oxide-zinc cell [22].

The electrochemistry of the charge and the discharge process can be seen on Figure 7.

$$2AgO + H_2O + 2e \underset{\text{charge}}{\overset{\text{discharge}}{\longleftrightarrow}} Ag_2O + 2OH^-$$

$$Ag_2O + H_2O + 2e \longleftrightarrow 2Ag + 2OH^-$$

$$Zn + 2OH^- \longleftrightarrow Zn(OH)_2 + 2e$$

$$Zn(OH)_2 + 2OH^- \longleftrightarrow Zn(OH)_4^{2-}$$

Overall Reaction

$$AgO + Zn + H_2O \longleftrightarrow Ag + Zn(OH)_2$$

Figure 7. Silver-zinc Electrochemistry [13]

The voltage drop during the charge end the discharge process can be seen on left side of Figure 8.

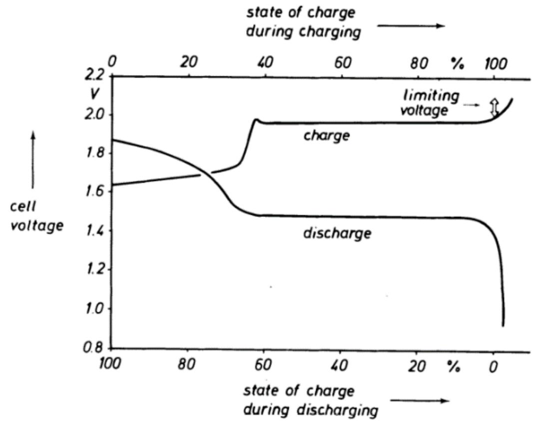

Figure 8. Cell voltage during charging and discharging as a function of the state of charge (percentage of the nominal Ah capacity) [22]

Figure 9 shows the comparison of the characteristics of 5 different battery types.

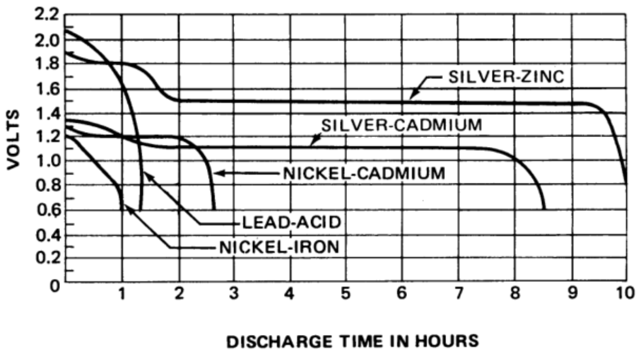

Figure 9: Comparison of discharge times of silver-zinc battery with other types (all the same weight) [5]

Reconfiguration of cells in a silver-zinc battery can improve the life time. [20, 23]

The main advantage of this battery technology is the highest specific energy and energy density. It has high discharge capability and it has good charge retention. Silver-zinc batteries have a flat discharge voltage curve [13].

The main disadvantage of this battery technology is the low cycle life. It has limited wet life (3-18 months, fill/activate prior to use) and it is sensitive for overcharge [13]. The high price of the silver cathode is also a disadvantage.

4 Application of Silver-zinc batteries

Silver zinc batteries are used not only the field of aircrafts. There are other applications exist:

4.1 Television and broadcasting

Electronic news gathering cameras, video tape recorder, portable lighting [5]

4.2 Portable industrial instrumentation

Ultrasonic detectors, court recorders, thermocouple sensors, inventory devices, methane detectors, miners' lamps, crane control, oxygen mask tester, underground radios, floodlights, measuring and controlling instruments, converters, emergency power supply of data-processing machines, flash and film lights in cameras [5]

4.3 Medical instrumentation

Ambulance emergency transceiver (portable), heart action recorder, portable organ transfer and storage devices, hand-held physicians' examining light, portable cystoscope, portable operating-room lighting (emergency), portable defibrillator [5], intelligent cloths [26]

4.4 Oceanographic exploration

Commercial submersibles, underwater seabed surface mining devices, underwater lighting portable cameras [5, 15]

4.5 Aerospace and communications

Balloon flight powering instrumentation, rocket instrumentation, stabilized aero static balloons (tethered), portable telephones in future computerized systems, portable heavy-duty radios, telemetry, energy storage for solar converters, launcher (satellites), energy systems, helicopter and aircraft batteries, portable receivers and transmitters, systems for emergency lighting [5]

4.6 Computers and microprocessors

Portable power for microprocessors and data banks, computerized portable weighing scales, portable paddles for inventory of stock in stores fed to computer [5]

4.7 Vehicles

Power for electric vehicles, remote-controlled model planes, ships, trains, drones [5, 14]

4.8 Military

Torpedoes, submarines, noiseless running combat vehicles, detonation systems, rocket power supply, radio transmitters, night vision equipment [4, 5, 11, 12, 13, 15, 18, 20, 23]

4.9 Space

Launch-vehicle guidance and control, telemetry, NASA vehicles Lunar Rover and Mars Rover, space shuttle payload launch and power for the life-support equipment used by the astronauts during Extravehicular Activities (EVA). [9, 13]

5 Comparison

There is no better technology then the Ag/Zn in the world of small batteries [7, 6]. In the field of higher size and higher capacity the lithium based and silver-zinc technologies have similar performance. Silver-zinc battery can provide high energy with a rather small mass, can be used in a low-temperature condition, and encompasses a sufficient shelf life, it is expensive and has a shorter use time compared to other secondary batteries. In most cases, the silver-zinc battery is used when space and weight are the most important [18]. Kennedy et al. have compared Li-ion and Ag/Zn batteries during the construction of a solar car. The car was faster with 1 km/h in the case of the lithium accumulator. [16] Kulshrestha et al. have compared Silver-zinc and Lithium-ion batteries using hybrid AC/DC Fighter Aircraft. The replacement of silver zinc battery with lithium ion battery has enhanced the overall performance of the aircraft system in their case. [17] The silver-zinc battery is better choice, in the case of MEA hybrid systems, where the motor starting current is very important. Higher safety level can be provided with Ag/Zn batteries.

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