TELEDYNE FLIR

WHITEPAPER
Predictive Maintenance

FIRE AND SAFETY IN THE EV INDUSTRY

Solutions for the upcoming Electrical Vehicle industry using temperature monitoring

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INTRODUCTION

The electric vehicle or EV industry has been growing exponentially over the last few years. It has gained popularity due to the alarming crisis of climate change and an urgent need to find an alternative to current fuel powered vehicles.

Since, the demand of electric vehicles has escalated significantly so has the production and manufacturing of battery packs and the challenges associated with it. This surge in production of electric vehicles has also brought forward multiple headlines of fire incidents. These incidents are not localized to small businesses but also include companies like Tata, TESLA and OLA. This topic is very fast and there might be multiple reasons behind all the incidents.

One of the high-tech solutions that can help to reduce few incidents is thermal imaging. This paper covers predictive maintenance and material research of electric vehicles.

To understand the application, we need to first understand some basics. Hence, I will cover the same before discussing the main applications.

BASICS OF LITHIUM-ION BATTERIES

Amongst the multiple appealing factors of lithium-ion batteries, one of the most notable attractions is the combination of electronegativity of lithium and its low density. This combination is responsible for producing the largest amount of electrical energy per unit weight among solid elements.

A standard lithium-ion battery contains an anode and a cathode. Usually, lithium oxide is used for the material of the cathode and a carbon-based compound for the anode. The constant internal movement of electrons between cathode and anode creates the infamous rechargeable cell.

When a lithium accepting compound is placed as the cathode of the chemical cell, lithium ions begin to flow in the backward direction during the cycle of charging and discharging. Oxidation and reduction reactions in the battery cause the battery to charge and discharge. (fig. 1,2)

Source: Times of India

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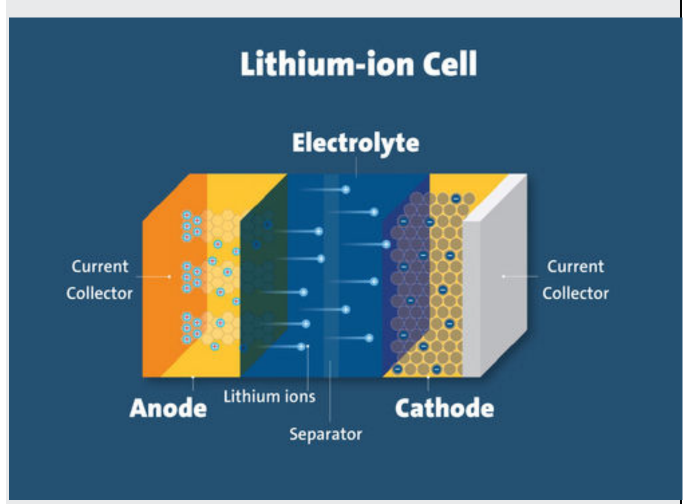


Figure 1. Source : UL Research Institutes

MANUFACTURING

1. Sorting

Usually, the cells are imported by the manufacturers in India and to ensure that no defective cell enters the manufacturing line, they are sorted manually by checking each cell for visible deformities, damage leakage and the range of the internal resistance. These factors determine the condition of the cell and ensure quality of the final product.

2. Making a pack

All cells are welded together in a pack in a combination of series or parallel depending on the required output specifications. This forms the basic structure of the battery pack. During this process the pack is checked by hand for weld deformities. The internal resistance and resistance determine whether the pack can be forwarded in the manufacturing line.

3. Combining the battery packs

The battery packs are connected using circuits and a control system. This culminates the process of manufacturing a lithium-ion battery pack and is distributed to companies making electric vehicles.

4. Testing

The finished product is put to test by undergoing cycles of charging and discharging. The behavior of the battery monitored during this process.

(fig. 3)

BASICS OF THERMAL IMAGING

The principle behind Thermal imaging is infrared radiation emitted by an object. This radiation is invisible to the human eye but can be seen using cameras optimized to its specific wavelength. (fig 4)

Although you can get a temperature estimate of a point using thermocouples, it can only provide the data of a single point at a time and the same needs to be in close contact with the object to measure. Using thermal cameras it is possible to see a wide range of such points and monitor the object's temperature without contact, from a safe distance and under running conditions. These thermal cameras can measure the temperature with a precision of 0.1 degrees Celsius.

Thermal imaging is widely used in other industries for fire and safety because it is a method of testing and monitoring which is non-contact and non-destructive.

VISIBLE VS IR

It is only possible to see the heat signature of an object when it reaches a temperature of 1000 degrees C. However, an infrared camera can capture heat signatures of objects as low as -60 degrees C using its infrared detectors.

Infrared technology is accessible in the absence of light but it is very different from a night vision camera. The wave lengths of both cameras are different.

A night vision camera amplifies small amounts of light, however a thermal camera picks up on heat signatures emitted by objects. Infrared cameras can be used in absolute darkness. (fig. 5)

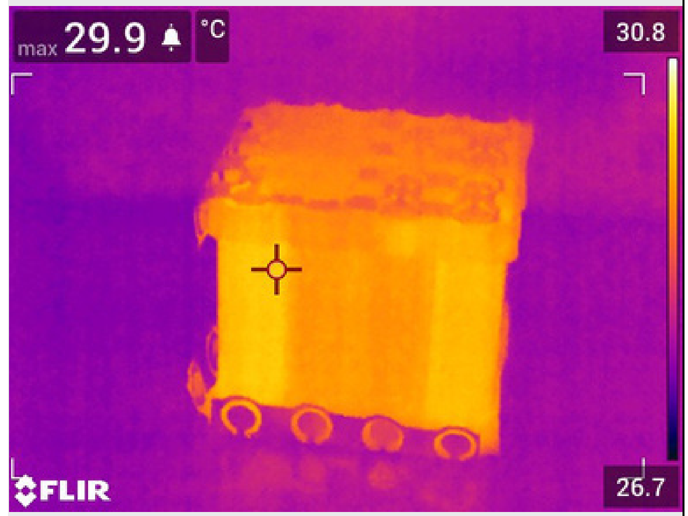


Figure 2. Thermal image of a battery pack consisting of LI-ion cells

Figure 3. Nissan, Sunderland, U.K. Plant
Source : www.greencarreports.com

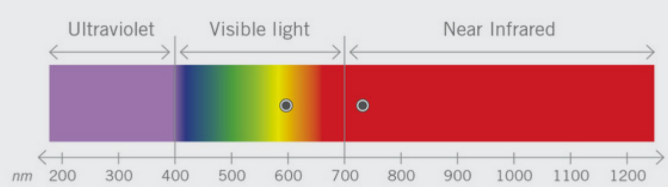


Figure 4. Source : UL Research Institutes

Figure 5. A lion in Infrared vs Night Vision

SOME CHARACTERISTICS

There are some limitations to this technology, an infrared camera can not see through glass as it only reads surface temperatures.

However, this technology has the ability to see through fog, thin plastic and an infrared inspection window which can be installed in factors to see through surfaces.

The resolution, lens size and the number of detectors determine how far one can see from the infrared camera. (fig. 6)

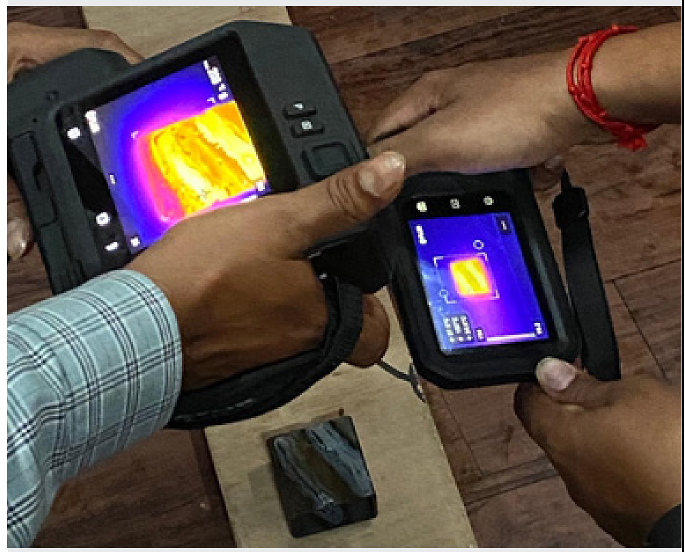
Figure 6. Infrared inspection window
Source : Teledyne FLIR

SOME APPLICATIONS

Thermal cameras are actively used for various applications in different industries.

Some of the examples of its applications are:

- Electrical utilities for predictive maintenance
- Oil & gas industry for predictive maintenance,
  visualization of VOCs, furnace inspection and flare monitoring
- Manufacturing companies
    - *Predictive maintenance*
    - *Quality insurance*
    - *R & D*



APPLICATIONS OF THERMAL IMAGING IN EV INDUSTRY

WELDING

Lithium cell units need to be welded together to form a battery back. However, if the welding is not done properly, faults may arise in the final product. The resistance and output may be affected and the longevity of the battery is directly affected. Usually, welding is checked manually by the factory workers which is a destructive method of testing, with which the cell may be ruptured.

A non-destructive and non-contact method to check the welded joint is by using thermal imaging. We can easily detect a poorly welded joint due to the slightly different temperature displayed by its seam. An uneven seam or a slightly raised temperature indicates faulty welding.

This method of testing already prevails across industries in the United States.

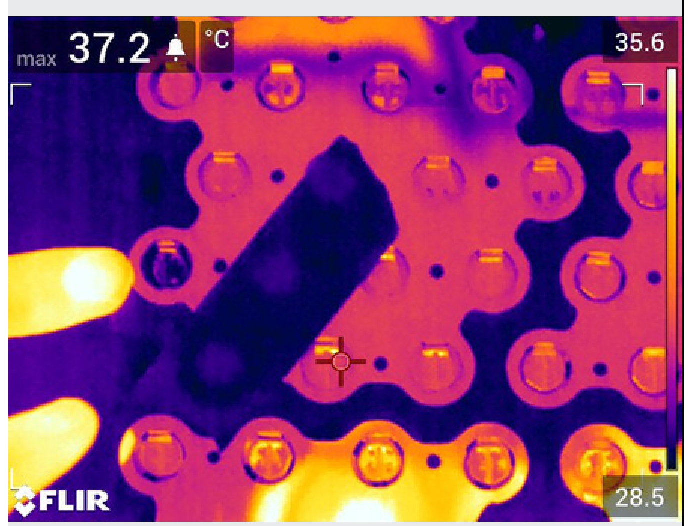


Figure 7. Cell leak identification using T-Series camera

CELL LEAKAGE

Almost invisible to the naked eye, cell leakage can occur at any time during the manufacturing process and can damage the battery pack. A cell that is leaking can be extremely dangerous if it comes in contact with the skin. We can use methods like the mass spectrometer to detect leakage but there is a better method to detect these small leakages: thermal imaging.

When the seal of the cell is ruptured, the liquid is deposited on the outer layer of the cell and a temperature difference is detected. A high resolution thermal camera can efficiently identify these minute leakages within a matter of seconds without contact as shown in figure. (fig. 7)

UNEVEN HEATING

Although with thorough testing at every stage, sometimes a faulty cell might still enter the production line. During the testing phase, faulty cells may display a slight temperature difference. This may be invisible to the human eye but can be easily captured using a thermal camera.

As seen in figure 8, the slightly elevated temperature is captured by the camera with a temperature reading accurate to the decimal.

Another example of uneven heating during manufacturing is during testing of the battery packs after assembling them. During the charge and discharge cycles, battery packs tend to heat up. However, during this testing phase, there is a high risk of the battery pack catching fire if the temperature is not monitored. This can be done using a thermocouple, a non-destructive contact method but it is only possible to monitor the temperature of one point at a time. If a lithium battery back catches fire in the facility, it will be really difficult to put out as lithium reacts really fast and the fire is difficult to put out because lithium reacts with water when in contact. (fig. 8)

CHARGING AND DISCHARGING

The last phase of testing includes charging and discharging the lithium-ion battery. During this phase, the temperature of the battery pack may rise to 5 or 6 degrees Celsius above the ambient temperature. Using a thermal imager, we can record the surface temperature of the lithium-ion battery pack and estimate the internal temperature without touching it.

We can clearly see the hotspots in the battery pack through the surface while it is being charged. This helps us isolate a potential issue and the location of the issue. (fig. 9)

Batteries being tested can be monitored around the clock to prevent potential fires if any unit heats up.

EV VEHICLE

The EV vehicle comprises of 3 main components, the battery, motor and invertor. Once the vehicle is assembled, thermal technology can be used to monitor its temperature behavior while its being used. (fig. 10)

This application is extremely valuable considering the recent rise of EV fires in India as it doesn't only provide solutions for battery manufacturing but also is capable of monitoring other components of the machine. (fig. 11)

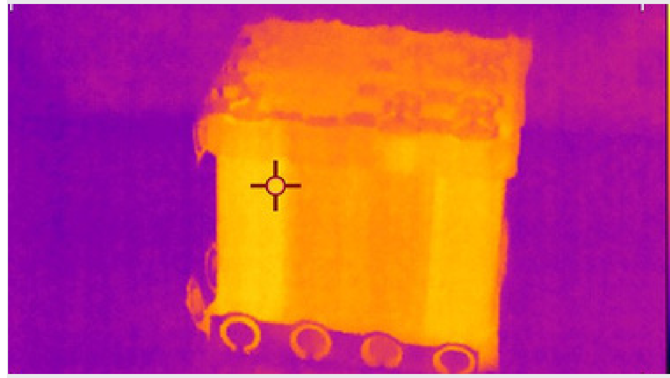


Figure 8. Uneven heating displayed by lithium battery unit

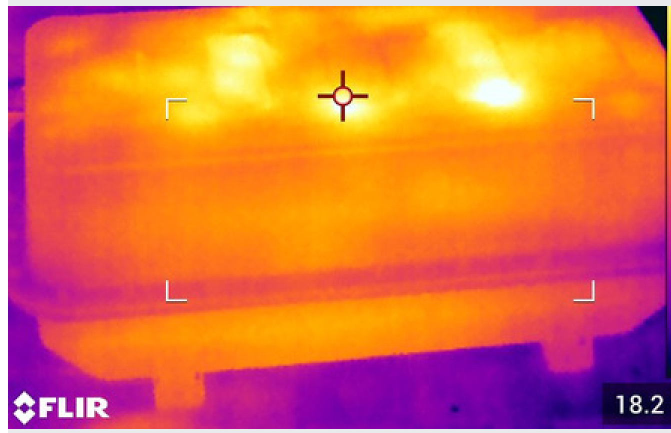


Figure 9. A battery pack in charging cycle

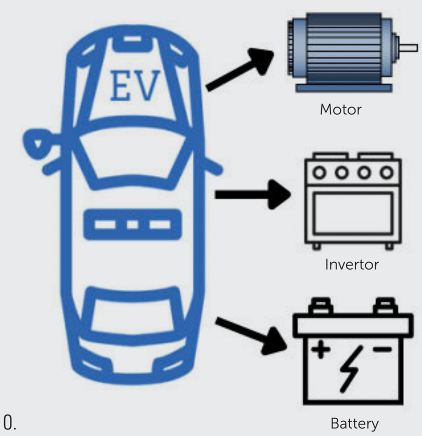
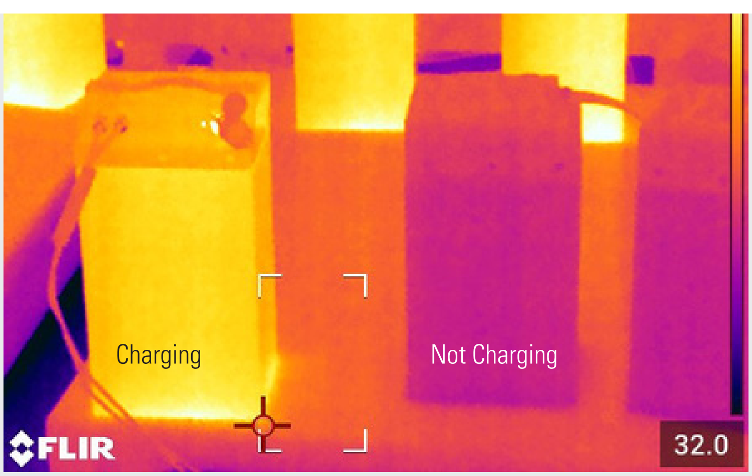


Figure 10.



Batteries undergoing charging and discharging cycle

Figure 11. An image of the interior of an EV

CONCLUSION

Although they are multiple preventative methods that can be used in the line of production of electrical vehicles, this solution provides predictive maintenance, fire and safety for this particular industry. Thermal imaging can be applied at various steps during the manufacturing process to monitor the target object and check for defaults.

This technology is not only useful for identifying defects and malfunctioning but it is crucial for the safety of the labor involved in manufacturing, as well as the customer using the finished product as electrical vehicles, which are prone to catching fire if not used or maintained correctly. The use of this technology promotes safety as it quickly picks up slight temperature differences and identifies uneven heating which are symptoms of a machine before it catches fire.

Although faulty systems might slip through manual inspection, it is highly unlikely that it does not get picked up using a thermal camera as it operates in the Infrared range converting heat signatures into a visual.

As the demand and supply both increase in this industry, so will the need to have more reliable testing and data for prevention and safety, in which thermal imaging proves to be a more than viable option to reduce to probability of and electrical vehicle from failing.

For more information about thermal imaging cameras or about this application please visit : https://www.flir.com/instruments/manufacturing

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